ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

VOLUME XVI. NUMBERS 1, 2 AND 3-4

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

No. 1—INTRODUCTION

No. 2—FAMILY ALEPOCEPHALIDAE

No. 3—FAMILY ARGENTINIDAE

BY WILLIAM BEEBE

PUBLISHED BY THE SOCIETY
THE ZOOLOGICAL PARK, NEW YORK

August, 1933-34

THESE THREE NUMBERS OF ZOOLOGICA

SETTING FORTH

THE FIRST MONOGRAPHIC STUDIES

OF THE DEEP-SEA FISHES OF BERMUDA

ARE PUBLISHED THROUGH THE GENEROSITY OF

HERBERT L. SATTERLEE, ESQ.

A PATRON OF THE ZOOLOGICAL SOCIETY

Zoologica, Vol, XVI, No. 1

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

INTRODUCTION*

By William Beebe

§ The value of these contributions to the ecology of deep-sea fish lies chiefly in the fact that the specimens concerned were all taken in thirteen hundred and fifty nets, drawn in one locality. This locality is an eight-mile circle, with its center at 32° 12′ North Latitude, and 64° 36′ West Longitude, nine and a quarter miles south-south-east of Nonsuch Island, Bermuda. Vertically, this is an imaginary cylinder, considered as extending from the surface to the bottom of the sea, an extreme range of fifteen hundred fathoms. Further details as to locality, dates, methods of work and net data may be found in Volume XIII of Zoologica, on pages 1 to 45.

Important new physical data of this particular locality have recently been supplied by a special oceanographic station established by the research ketch Atlantis, of the Woods Hole Oceanographic Institution. In August 1931 it was in Bermuda and at my expressed wish, Dr. Henry B. Bigelow kindly allowed the Atlantis to make a station at the exact center of my area of exploration. Under the direction of Dr. H. R. Seiwell this work was carried out on August 27th, from 5:50 to 7:38 P. M. (1750 to 1938), in 32° 11′ North Latitude, and 64° 36′ West Longitude. The temperatures agree with those taken on several occasions by the Staff of the Zoological Society.

The following physical data were obtained:

---

* Contribution, New York Zoological Society, Department of Tropical Research, No. 416.

Depth			Temperature		Salinity	d +	0_2 cc/L	PH	$PO_4 M_9/M_3$
Meters	Fathoms	Feet	Cent.	Fahr.					
0	0	0	28.10	82.6	36.50	23.52	4.5	8.45	12
25	13.6	81.6	28.02	82.43	36.45	23.51	4.5	8.49	12
50	27	162	21.77	71.2	36.61	25.53	5.5	8.46	12
100	54.6	327.6	19.02	66.25	36.59	26.24	4.9	8.46	12
200	109	654	18.24	64.8	36.555	26.42	4.8	8.45	14
300	164	984	17.93	64.3	36.50	26.46	4.7	8.41	15
400	218.7	1312	17.30	63.1	36.40	26.54	4.4	8.39	19
600	328	1968	14.47	58	35.91	26.80	4.3	8.23	26
800	437	2622	10.27	50.5	35.35	27.20	3.4	8.11	49
995	544	3264	6.76	44.2	35.075	27.53	4.3	8.10	47
1194	653	3918	5.29	41.5	35.08	27.72	5.2	8.08	46
1593	871	5226	3.96	39.1	34.99	27.81	6.0	8.06	45
1993	1089.8	6539	3.54	38.4	35.04	27.89	6.0	8.15	46
2492	1362.6	8176	3.205	37.8	34.965	27.87	5.9	8.08	48

Depths at 200, 400, 800, 995, 1593 and 1993 meters by unprotected thermometer.

Position of Fishawk Snapper Sample: 32° 10′ 53″ N. Lat., 64° 36′ 57″ W. Long.

§ The following methods of procedure require special comment:

MEASUREMENTS:

Length: All measurements of length refer to standard length (snout to base of caudal fin) unless otherwise specified.

Eye: The eye diameter is the greatest external width of the eyeball, as the deeply pigmented iris is frequently shrunken and the whole eye enclosed in a thick, transparent capsule in the Alepocephalidae and Bathylagidae.

Interorbital: The interorbital breadth is measured between the bony, interorbital ridges at the *plane through the middle of the eye.*

Interocular: The full width between the external free margins of the thin, lamella-like supraorbital expansions of the frontals, *at the plane through the middle of the eye.*

Stomach: Unless otherwise specified, the stomach is measured from the anterior end of the intestine to the tip of the blind sac, due to the frequent lack of any sharp demarcation between the oesophagus and the stomach proper.

DEVELOPMENT: In an attempt to work toward a uniformity of terminology and a ready means of classification of deep-sea fishes in various stages of development, the following stages are recognized, defined in general as follows:

Larva: Fish entirely free of egg membranes but with remains of yolk sac present, or with intestinal tract lying open externally along the ventral profile, not enclosed within body cavity.

Post-larva: No yolk sac; intestine (except protruding posterior tip) enclosed within body cavity.

Rays of paired fins only partially differentiated.

Ossification lacking, or with traces in head only.

Adolescent:

Rays of paired fins fully differentiated, though usually unossified.

Ossification incomplete.

Gonads immature.

Adult: Ossification complete.

Gonads fully developed.

In the various species the stages are usually well defined by differences of proportion, pigmentation, dentition, etc. in addition to the basic distinctions just listed. The differences between larva and post-larva are in general more pronounced than those between succeeding stages.

The change from one stage to the next is, of course, gradual, and transition forms frequently occur, distinguished by vestigial characters of the early stage combined with partially developed traits of that succeeding. Although these transitional specimens are in some cases closer to the later than the earlier stage, for the sake of uniformity they are always counted with the earlier stage in all totals where they are not separately named.

ECOLOGY: Due to adverse weather conditions the total numbers of nets drawn, during the months of the three trawling seasons from April through September, were not equal. Thus in September, between 400 and 1000 fathoms, six times as many nets were drawn as in April, nearly twice as many as in May, and so on. In order to determine what difference an equal chance each month of catching specimens might make in the total monthly numbers, the following procedure was followed: The sum of the specimens taken over the three-year period during the same month was multiplied by the quotient of the total number of nets drawn (between the limits of

the species' Bermuda vertical distribution) during September, the month of maximum number of hauls, divided by the total number drawn during that month between the same depths. Thus, in July during 1929, 1930 and 1931, 20 specimens of *Bathylagus glacialis* were taken. The vertical range of the species off Bermuda is from 500 to 1000 fathoms. Altogether 178 nets were drawn in July between these depths, while 288 were pulled during the three Septembers. Therefore, 20 is multiplied by 1.6, giving a product of 32, the total number of specimens that theoretically would have been taken had the maximum number of nets been drawn in July. The dotted lines on the graphs of seasonal distribution represent the result of these computations, *always, of course, accompanied by the solid line of actual results.* In general, the relative result, for purposes of drawing distributional conclusions, is very little changed.

The total numbers of nets drawn at the depths from 500 to 1000 fathoms are practically identical as may be seen from Zoologica, Vol. XIII, No. 3, p. 37. At 400 fathoms, however, only one-third as many nets were drawn. For this reason, on the graphs of vertical distribution 400-fathom-totals have been multiplied by three and this theoretical result indicated by a dotted line above the *solid line which represents the actual totals.*

In working out the limits of the vertical distribution of the various species throughout the world from previously published records, the possibility of the capture of specimens in the course of hauling in the net has been ignored. Where specimens were taken in vertical nets the maximum depth is used.

In calculating the average depths and lengths of the Bermuda specimens, standard deviations have been disregarded, as they were found to be too slight to be of any practical value.

The following arbitrary divisions are made in defining the abundance of a species:

Abundant: More than 30,000 specimens taken (Example, *Cyclothone signata*)

Plentiful: 1000 to 3000 specimens taken (Example, *Myctophum laternatum*)

Common: 500 to 999 specimens taken (Example, *Sudis bronsoni*)

Fairly common: 100 to 499 specimens taken (Example, *Argyropelecus hemigymnus*)

Uncommon: 50 to 99 specimens taken (Example, *Bathytroctes rostratus*)

Rare: 15 to 49 specimens taken (Example, *Bathytroctes drakei*)
Very rare: 1 to 14 specimens taken (Example, *Dolichopteryx longipes*)

§ The Bermuda collection contains the following new genera and species:

ALEPOCEPHALIDAE:

Anomalopterus megalops Beebe 1933
Dolichopteryx binocularis Beebe 1932
Macromastax Beebe 1933
Macromastax gymnos Beebe 1933
Photostylus Beebe 1933
Photostylus pycnopterus Beebe 1933

LIST OF SPECIES

Family ALEPOCEPHALIDAE

Family ARGENTINIDAE

SUMMARY OF IMPORTANT POINTS

First Two Families

ALEPOCEPHALIDAE:

General: Prevalence of light organs of most varied types. Deep pigmentation of larvae and post-larvae. Great majority of Bermuda specimens immature.

Genera and Species:

Anomalopterus megalops: New species, with light organs. Second known specimen of the genus.

Bathytroctes drakei: A species known previously only from the type, taken by Beebe from Hudson Gorge in 1928. Full descriptions of young stages.

Bathytroctes rostratus: First record from western Atlantic. Discovery of biserial tooth stage. Evidence that light organs are limited to adolescent stage. First description of digestive organs.

Dolichopteryx binocularis: New species with scales and a ventral luminous organ. First description of the osteology of *Dolichopteryx.*

Dolichopteryx longipes: Discovery that specimens as small as 35 mm. are well ossified, almost ready for breeding. Digestive and reproductive organs described for first time.

Macromastax gymnos: New genus and new species which supplies a link between the scaled, *Bathytroctes*-like Alepocephalids and the tubercled, *Xenodermichthys*-like group.

Photostylus pycnopterus: New genus and new species with curious, stalked, light organs, and a striking resemblance in general form to a Melanostomid larva.

Xenodermichthys copei: Genus taken for second time in western Atlantic. Definite arrangement of light organs evident.

ARGENTINIDAE:

General: Occurrence of light organs in at least one species; luminescence previously unknown in family. Great majority of Bermuda specimens immature.

Genera and Species:

Bathylagus benedicti: Young specimens taken for first time. Most of these occurred in the spring, showing definite relation between length and season.

Bathylagus glacialis: First occurrence in western Atlantic; tends to have a very slightly smaller head and eye than eastern specimens and an extra pelvic finray. Young described for first time. Post-larvae have stalked eyes and definite pigmentation patterns. Adults and some adolescents have luminous abdominal scales and luminous bands on the anal and lower caudal; this not only alters the definition of the family, but at least partially refutes Günther's theory that they have enormous eyes to make up for their

own lack of luminous organs. Average depth found to be 100 fathoms higher in spring than in late summer and fall. Osteology described for first time in the genus. First description of digestive and reproductive organs and of eggs.

§ In the recording and correlation of the data of the present paper I have had the constant and invaluable assistance of Miss Jocelyn Crane, Laboratory Associate on my staff. Our work began with the specimens as they were taken from the nets, still living or just dead, and in the majority of cases, measurements and descriptions have been made before preservation.

All skeletons, as a whole or in part, are described from dyed and cleared specimens prepared by Miss Gloria Hollister, Research Associate, whose preparations have reached almost the acme of excellence.

The line drawings are by Mrs. Helen Tee-Van and Mr. Edward Delano.

Zoologica, Vol. XVI, No. 2.

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

Family ALEPOCEPHALIDAE*

By William Beebe

(Figs. 1–25 incl.)

* Contribution, New York Zoological Society, Department of Tropical Research, No. 417.

Zoologica, Vol. XVI, No. 2.

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

Family ALEPOCEPHALIDAE

By William Beebe

(Figs. 1–25 incl.)

Isospondylous fishes with the border of the upper jaw formed by the premaxillaries and maxillaries; teeth feeble; head naked; scales (when present) thin, deciduous, cycloid; no stout, spinous finrays; dorsal and anal set far back, nearly opposite; no post-dorsal adipose fin; no barbel; light organs present or absent; no serial photophores in double row close to ventral profile; pseudobranchiae present.

Deep-sea fish of temperate and tropical seas, apparently absent from the arctic and antarctic.

Seventeen genera are known, including two here described for the first time.

The Bermuda Oceanographic Expeditions captured 128 specimens of the family, distributed among 8 species and 6 genera.

Of the 13 families of deep-sea Isospondyls represented in the same collection, the Alepocephalids are seventh in order of numerical, third in specific and second in generic abundance.

Key to the Genera

A. Snout elongated, tube-like, mouth at tip.
  a. Anal about equal to or shorter than dorsal..... *Dolichopteryx*
  aa. Anal much longer than dorsal..... *Aulostomatomorpha*
AA. Snout short or moderate.
  B. Pelvics absent..... *Platytroctes*
  BB. Pelvics present.
    C. Vertical fins very long (D. 48, A. 71)..... *Leptoderma*
    CC. Vertical fins short or moderate.
      D. Mandible toothless..... *Ericara*
      DD. Mandible with teeth.
        E. Upper jaw toothless.
          a. 13 branchiostegal rays..... *Leptochilichthys*
          aa. 5 branchiostegal rays..... *Asquamiceps*

EE. Upper jaw with teeth, at least in premaxillary.
F. A dermal fold in front of dorsal.
a. Head large (2 in length) ..... *Anomalopterus*
aa. Head small (6 in length) ..... *Photostylus*
FF. No dermal fold in front of dorsal.
G. Body completely scaled.
a. Maxillary toothless.
b. Premaxillary normal, jaws about equal in front .... *Alepocephalus*
bb. Premaxillary expanded, forming a nearly horizontal plate enclosing mandible ..... *Xenognathus*
aa. Maxillary with teeth.
b. Teeth in premaxillary pluriserial ..... *Narcetes*
bb. Teeth in premaxillary uniserial.
c. A large, forwardly-directed, symphysial knob ..... *Bajacalifornia*
cc. Symphysial knob minute and ventrally directed, or absent. *Bathytroctes*
GG. Body naked (or with minute scales in lateral line).
H. Dorsal twice as long as anal and originating in advance of it ..... *Macromastax*
HH. Dorsal and anal equal and opposite.
a. Dorsal and anal 15 to 21 ..... *Rouleina*
aa. Dorsal and anal 27 to 30 ..... *Xenodermichthys*

VERTICAL DISTRIBUTION OF THE SPECIES OF ALEPOCEPHALIDAE TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

Species	Fathoms										
	0	100	200	300	400	500	600	700	800	900	1000
Anomalopterus megalops	–	–	–	–	–	–	–	×	–	–	–
Bathytroctes drakei	–	–	–	–	×	×	×	×	×	×	–
Bathytroctes rostratus	–	–	–	–	–	×	×	×	×	×	×
Dolichopteryx binocularis	–	–	–	–	×	–	–	–	–	–	–
Dolichopteryx longipes	–	–	–	–	–	–	×	×	×	–	–
Macromastax gymnos	–	–	–	–	–	–	–	–	–	–	×
Photostylus pycnopterus	–	–	–	–	–	–	–	–	×	–	–
Xenodermichthys copei	–	–	–	–	–	–	×	×	–	–	–

Genus **Anomalopterus** Vaillant 1888

Large-headed Alepocephalids with a dermal fold along the dorsal profile in front of the dorsal fin. Elongate; moderately compressed; scales absent; mouth large; teeth present on premaxillaries and mandible, sometimes on maxillary or palatine as well; gill opening large; paired fins short, inserted close to ventral profile; dorsal originating slightly in advance of anal and having fewer rays.

Two species, from off Morocco and Bermuda respectively.

Anomalopterus megalops Beebe 1933

(Fig. 1)

TYPE: Department of Tropical Research No. 11,456; Bermuda Oceanographic Expedition of the New York Zoological Society; Net 280; July 10, 1929; 12 miles south of Nonsuch Island, Bermuda; 700 fathoms; Standard length 31 mm.

Fig. 1. *Anomalopterus megalops* Beebe. × 3

MEASUREMENTS AND COUNTS: Standard length 31 mm; depth 7.8 (in length 4); head 15.3 (in length 2); maximum thickness 6.5 (in length 4.8); eye diameter, without fold, 3.3 (in head 4.6); eye fold .48; snout 3.8 (in head 4); maxillary 8.2 (in head 1.9); interorbital 2.4 (in head 6.4); brachiostegal rays 7, the membranes partially united beneath the isthmus; pectoral rays 7; pectoral length 1.9; pelvic rays 7; pelvic length 2.5; dorsal rays 21; anal rays 20.

EXTERNAL CHARACTERS: The color in the fresh specimen was a dark sepia brown, while the very thin epidermis was transparent, adhering closely and resembling cellophane in its texture.

The contour of this fish is very unusual, being deepest at the

mid-body, sloping gradually forward to a deep, blunt snout, and more rapidly posteriorly, ending in an elongated, slender peduncle. The enormous head is half as long as the entire fish, and the correspondingly large eyes are contained four and a half times in the head. The head slopes evenly to the snout when it descends in an abrupt curve to the mouth. A curve corresponding to that of the nape follows the mandible back to its posterior angle, and from here to the tail the ventral contour is horizontal. The mid-back, throughout the extent of the predorsal fold, is horizontal, the remaining contour, from the anterior insertion of the dorsal fin, descending in a steep, long curve to the caudal fin.

The large eyes are high on the head, interrupting the dorsal profile, and the eye-ball is surrounded by a thick, fleshy fold, making these organs look even larger than they are. The nostrils are conspicuous, slightly nearer the anterior margin of the eye than tip of the snout, and are above a line drawn between these two places. The narial area is very large, measuring a millimetre in diameter, and it is difficult to understand Vaillant's foot-note in the description of *A. pinguis* (1888, p. 161), "Je n'ai pu découvrir les narines." The interorbital breadth is only three-quarters the diameter of the eye.

The mouth is large, with a slight downward slope posteriorly, the maxillary ending just short of the posterior vertical of the eye. The teeth are small, slightly curved and present on the premaxillary, maxillary and the anterior part of the mandible. The maxillary teeth are seven in number and alternate with shallow, rounded scallops. The vomer and palatines are edentulous.

The gill openings are large; the opercula are covered with skin and the posterior margin is smooth. The branchiostegal rays are seven in number and partially united beneath the isthmus.

The lateral line begins at the upper angle of the gill openings, and in the anterior third of the trunk length descends to the midline, holding level back to the tail.

The skin is scaleless and smooth except for numerous small tubercles, abundant on the head, and less so on the body, where they are scattered along the dorsal fold and the lateral line, around the anus and at the base of the caudal fin. They are asymmetrically distributed over the two sides of the fish, but show a decided tendency toward a linear arrangement, which argues the presence of a defi-

nite pattern in life. Especially noticeable is the curving line about the tip of the snout and along the maxillary, several short lines in the center of the opercular region, and others along the posterior outline of the mandible. They are very easily rubbed off in the preserved specimen.

The dorsal fold is a low dermal ridge which begins at the nape and extends halfway down the back.

The pectoral fin, inserted but little above the ventral profile, has 7 very short rays, and the pelvic, with an equal number, originates well in advance of the dorsal fin. The latter has 21 rays and occupies about the middle third of the back, encroaching considerably upon the posterior extension of the dermal fold. The anal fin, of 20 elements, occupies the same antero-posterior extent as the dorsal, but extends about half its length behind the dorsal. The caudal is badly injured and the length is uncertain.

DISCUSSION: My specimen No. 11,456 must be referred to the genus *Anomalopterus* on the basis of the two dominant generic characters—the enormous size of the head and the presence of the adipose fold preceding the dorsal fin, unless a new genus be made due to the presence both of maxillary teeth and of dermal tubercles in the present specimen.

The only other species, and in fact individual of the genus, *Anomalopterus pinguis*, was described by Vaillant (1888, p. 160–162; pl. XI, fig. 4, 4a). It was taken on the voyage of the Talisman in 1883, near Cape Blanco, Morocco, at a depth of 1400 metres, or 765 fathoms.

Anomalopterus megalops differs from Vaillant's species in the much larger eye, the presence of teeth on the maxillary, the conspicuous nostrils, increased vertical finray counts and the presence of tubercles on the skin.

Even allowance for a difference in age (*pinguis* is twice as long as *megalops*) could not account for the greatly disproportionate size of the eye, the inconspicuousness of the nostrils and the total absence of dermal tubercles.

The following table presents a direct comparison between the two individuals of the two species:

	Anomalopterus pinguis Vaillant	*Anomalopterus megalops* Beebe
Length	61 mm.	31 mm.
Lgth: depth	3.6	4
Lgth: thickness	7.6?	4.8
Lgth: head	2.	2
Head: eye	20 (fresh, without fold)	4.6 (preserved, without fold)
Head: snout	3	4
Head: interorbital	8.6	6.4
Upper jaw	Nearly ½ head (from fig.)	Like pinguis
Maxillary	Extends beyond parallel from posterior border of orbit.	Ends in front of parallel from posterior border of orbit.
Teeth	Very small on premaxillaries and mandible; larger on palatines; none visible on vomer.	Very small on premaxillaries and mandible; maxillary with 7 small teeth alternating with very shallow scallops; none on palatines or vomer.
Nostril	"Je n'ai pu decouvrir les narines."	Conspicuous, slightly nearer anterior margin of eye than tip of snout, and above horizontal through the center of the eye.
Eye	With cutaneous fold which narrowed it greatly in fresh specimen.	Fold similar to *pinguis* but eye itself much larger.
Interorbital space	At least double length of eye.	Only three-fourths eye length, but latter is proportionately much greater. Compared with head, interorbital is broader than in *pinguis*.
Gill opening	Large.	Large.
Operculum	Covered in life by a membranous tegument and largely membranous itself. Only preopercle and opercle distinguishable. A furrowed border with posterior projections.	Similar, but no "furrowed border" nor posterior projections except several of the tubercles, which are generally distributed over the fish.
Skin	Absolutely naked.	Scaleless, but with small tubercles present on head and body.
Lateral line	Begins at upper angle of gill opening; descends rap-	Like *pinguis*.

	Anomalopterus pinguis Vaillant	*Anomalopterus megalops* Beebe
	idly to median line, follows latter to caudal.	
Adipose fold	Fold plus dorsal equals 80% of back. Fold occupies anterior 67% of fold plus dorsal.	Fold plus dorsal equals 62% of back. Fold occupies anterior 84% of fold plus dorsal.
	Lower than true dorsal. Extends to dorsal origin.	Similar to *pinguis* in general character, but neither as high nor as conspicuous. Reaches mid-dorsal.
Dorsal	17	21
Anal	14	20
	Extends slightly beyond dorsal and is not so long.	Extends slightly beyond dorsal and is about same length.
Pectoral	9—very short	7—very short
Pelvic	9	7
	Origin almost opposite rayed dorsal.	Origin well in front of rayed dorsal.
Color	Bluish; iris white.	Dark brown.

Type in the collections of the Department of Tropical Research of the New York Zoological Society.

Reference

Anomalopterus megalops Beebe 1933, p. 159; fig. 39. (Type description).

Genus **Bathytroctes** Günther 1878 (including *Talismania* Goode and Bean 1895)

Generic Characters: Form elongate, moderately compressed; body scaled; head moderately large; maxillary toothed, its posterior border not extending beyond the posterior margin of the orbit (except in *B. stomias*); teeth also present at least in premaxillary and mandible; symphysial knob, if present, small, ventrally directed; branchiostegals 7; paired fins short, inserted fairly close to ventral profile; dorsal fin equal to or longer than anal, originating opposite or in front of it.

Number of Species: At least nineteen species have been recorded; of these, two were taken by the Bermuda Oceanographic Expeditions.

GEOGRAPHICAL DISTRIBUTION: Members of the genus are known from the Atlantic, Mediterranean, Indian and Pacific Oceans.

VERTICAL DISTRIBUTION: *Bathytroctes* has been caught at depths all the way from 200 to 2700 fathoms; the Bermuda examples came from between 400 and 1000 fathoms, but were most abundant between 600 and 900 fathoms. In the trawling cylinder temperatures of about 52.8° Fah. and 38.7° Fah. were recorded at 400 and 1000 fathoms, respectively.

ABUNDANCE:

World: Bathytroctes rostratus is the only species of the genus of which more than five individuals have previously been taken. Of this species, about thirty-five specimens are recorded.

Bermuda: A total of 116 specimens of *Bathytroctes* have been taken by us. In the order of abundance of individuals in the nets, *Bathytroctes* ranks first among the Alepocephalids, eighth among the deep-sea Isospondyls (in a total of 42 genera) and about sixteenth among all the deep-sea fishes (including at least 120 genera).

SOCIABILITY: *Bathytroctes* is probably not gregarious: Practically always but one was found in a single net, rarely two, twice three, once four. On the other hand, in five instances individuals of both *B. drakei* and *B. rostratus* were taken in the same net, making it possible that schools of the young of the two species mingle as in shoals of whitebait—young herring and spratt.

FOOD: Of the twelve stomachs examined, eight contained food. This consisted entirely of small crustaceans and mollusks.

ENEMIES: *Bathytroctes* has not yet been found in the stomach of any animal, nor have parasites been observed.

VIABILITY: None of the Bermuda specimens has been brought alive to the surface.

SIZE: The largest specimen of *Bathytroctes* on record is the type of *B. aequatorius* which measures 362.5 mm. and was taken off the coast of Equador. The smallest is 9 mm. in length, recorded by Murray and Hjort (1912, Pl. IX) from off north-west Africa.

In the present collection the largest specimen of the genus is an immature *B. rostratus* of 56 mm.; the smallest is a larva of the same species measuring 9.5 mm. in length.

DEVELOPMENT: Post-larvae are by far the most numerous in the Bermuda collection; larvae and adolescents are rare; adults are absent. The first three stages were all taken throughout the April-to-September trawling seasons.

Brief Summary of Growth Stage Characters of Bathytroctes Based on the Bermuda Material

Key to Growth Stages:

A. Yolk sac present; head relatively one-half or less adult size ..... Larva.
AA. Yolk sac absent; head relatively adult size or longer.
B. Paired fins with rays not fully differentiated; no ossification ..... Post-Larva.
BB. Paired fins with rays well differentiated; ossification partial ..... Adolescent.

Larva: Yolk sac; feeble jaws; teeth almost or entirely lacking; moderate, nearly round eye; small head; pectoral a flap; pelvic absent; dorsal and anal semi-developed or still finfold-like; caudal strong, but heterocercal, no rays; pre-dorsal and pre-anal finfolds present; pigment well developed except on head; no ossification; 9.5 to 14 mm.

Post-larva: No yolk sac; jaws large and strong; teeth developing; eye large, elongate; relatively full size; head of adult proportions; pectoral and pelvic fins developing; dorsal and anal almost fully developed; no finfold; no ossification; 11 to 30 mm.

Adolescent: Pectoral and pelvic fully developed externally, but no ossification of the bases of any of the fins; skull and cleithrum moderately well ossified; gonads partly developed; 28 to 56 mm.

Key to the Bermuda Species of *BATHYTROCTES*

A. No black, supraclavicular process; anterior premaxillary teeth not projecting; snout about equal to diameter of entire eye capsule ..... *B. drakei*
AA. Black, supraclavicular process present; anterior pair of premaxillary teeth projecting, tusk-like; snout shorter than diameter of entire eye capsule ..... *B. rostratus*

Bathytroctes drakei Beebe 1929

Specimens Taken by the Bermuda Oceanographic Expeditions

27 specimens; May to September, 1929 to 1931; 400 to 900 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; Standard lengths from 10 to 22 mm.

The Species of *Bathytroctes* (including *Talismania*)

Species	*Authority*	*Locality*	*No.*	*Length (mm)*	*Fathoms*	*Meters*
aequatoris	Goode & Bean 1895	Equador	1	362.5	741	1355
alveatus	Garman 1899	Pacific Panama	2	187.5	1132	2070
alvifrons	Garman 1899	Pacific Panama	2	225	1360, 1793	2487, 3279
antillarum	Goode & Bean 1895	Caribbean	1	—	420	768
attritus	Vaillant 1888	Azores; N. W. Africa	4	250 (type)	789 to 1999	1442 to 3655
	Roule 1919	Near Azores	1	—	947	1732
calcaratus	Weber 1913	Macassar St.	1	265	396	724
		Ceram Sea	1	152	310	567
curvifrons	Roule & Angel 1933	Bay of Biscay	1	105	2461	4500
drakei	Beebe 1929	Hudson Gorge	1	29	800	1463
		Bermuda	27	10 to 22	400 to 900	732 to 1646
grimaldii	Zugmayer 1911	Morocco	1	165	2679	4900
homopterus	Vaillant 1888	Banc d'Arguin	1	161	609	1113
	Norman 1930	West Central Africa	3	47 to 100	328 to 492	600 to 900
inspector	Garman 1899	Pacific Panama	1	250	1471	2690
longifilis	Brauer 1902	Gulf of Aden	1	117	803	1469
macrolepis	Günther 1887	Off Celebes	1	225	2150	3932
melanocephalus	Vaillant 1888	Off West Africa	4	108 (type)	785 to 1422	1435 to 2600
microlepis	Günther 1878	S. E. of C. St. Vincent	1	250	1090	1993
	Alcock 1889	Andaman Sea	1	—	500	914
mollis	Koehler 1896	Bay of Biscay	1	318	930	1700
	Roule 1916, 1919	Azores	1	318	987	1805
rostratus	Günther 1878*		35	9 to 163	200 to 2600	366 to 4755
	N. Y. Zool. Soc. Exp.	Bermuda	89	10 to 56	500 to 1000	914 to 1829
squamosus	Alcock 1890	Arabian Sea	1		740	1353
	Weber 1913	Bali Sea	2	142, 165	557	1018
stomias†	Gilbert 1890	Off Oregon	1	325	877	1604

*See p. 55 for subsequent records from the Atlantic, Mediterranean & Indian Ocean.

†It seems probable from the description that this specimen is a species of *Narcetes* Alcock 1890.

Previously Recorded Specimen

Type only; 800 fathoms; Hudson Gorge, 125 miles south-east of New York City; Standard length 29 mm.

Specific Characters

(From the type specimen; Figs. 2C and 3B).

Bathytroctes drakei may be distinguished immediately from all other members of the genus by the shortness of the mouth. In the present species the posterior end of the maxillary does not quite reach the vertical from the anterior rim of the eye-ball, while in the

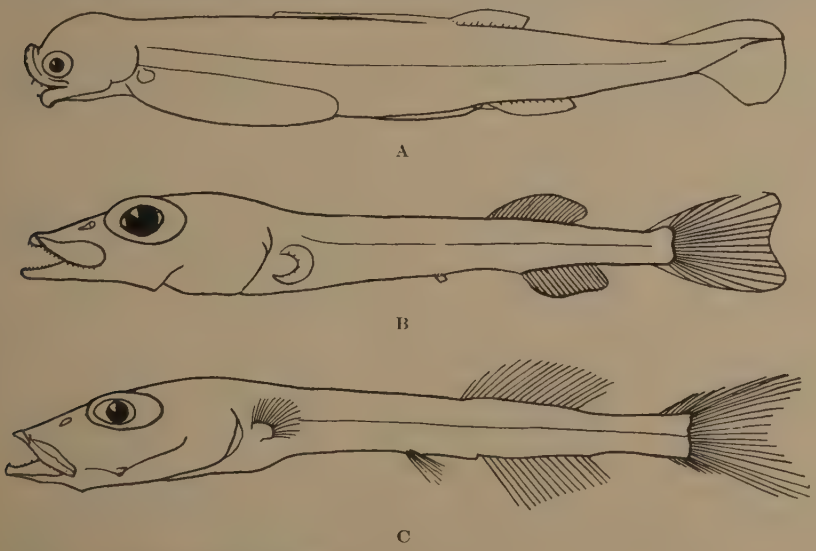


Fig. 2. *Bathytroctes drakei* Beebe. A, larva, 11.5 mm.; B, post-larva, 15 mm.; C, adolescent (type specimen), 29 mm.

rest of the species it extends at least to that from the middle of the eye. From *B. rostratus*, the other Bermuda species, it differs also in the more slender body (depth 10 in length, not 4.3 to 5), longer snout (3.2 in head instead of about 3.8), in the absence of protruding premaxillary teeth and in the lack of a supraclavicular process. *Color:* Light gray (brownish in preservative), with the head darker, and the opercles and abdomen nearly black. *Proportions:* Depth in length 10; head in length 2.8; eye in head 3; snout in head 3.2;

maxillary in head 3.4. *Fin Ray Counts:* Pectoral 16; pelvic 7; dorsal 18, originating in front of the anal; anal 15. *Teeth:* Present in premaxillaries (10 pairs), maxillaries (22 pairs), mandible (10 pairs), vomer (3 or 4 pairs) and palatines (about 3 pairs). All are minute, the premaxillaries and maxillaries about equal in size, those of the mandible even smaller, with wide spaces between.

Development

The 28 known specimens of *Bathytroctes drakei,* including the Hudson Gorge type, group themselves into the larval, post-larval and adolescent growth stages. The great majority of the specimens are post-larvae, there being but three larvae and one adolescent (the type). The relation of these growth stages to their standard length and numerical abundance in the Bermuda collection may be seen from the following table.

The Relation of Growth Stage to Length and Numerical Abundance in *Bathytroctes drakei*

Length in mm	Larvae	Transitional Larvae	Post-larvae	Transitional Post-larvae	Adolescents	Transitional Adolescents	Adults	Total
10–11	1							1
12–13	1	1	2					4
14–15	1		10					11
16–17			7	1				8
18–19			1					1
20–21				1				1
22–23				1				1
	3	1	20	3				27

Larva: (Fig. 2A). The three larvae, characterized briefly by the presence of a yolk sac and the lack of pelvic fins, measure 10, 11.5 and 14 mm respectively. The 11.5 mm specimen is described below:

Trawling Data: Department of Tropical Research No. 21,936; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1137; Aug. 6, 1931; 9 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 11.5 mm.

Measurements and Counts: Standard length 11.5 mm; depth 1.5 (in length 7.6); head 1.7 (in length 6.8); eye, horizontal, .48 (in head 3.1); eye, vertical, .38 (in head 3.9); snout .27 (in head 5.5); dorsal rays 13; anal rays 10.

External Characters: Body light brown; head, opercles and bases of fin rays white.

The sub-cylindrical, elongate body (excluding the yolk sac) is deepest between the yolk sac and the anal origin; posterior to this it tapers above and below to the slender, very slightly upturned urostyle. The yolk sac projects but little beyond the line of the ventral profile, and extends over about three-fifths of the distance between the opercles and the anus.

The head is small, the rounded crown being slightly higher than the nape. The brain (Fig. 3A) is enormous, nearly filling the top of the head from nostrils almost to the plane of the opercular margins. Relatively, it is twice as large as in the adolescent or over one-third the actual size of the latter, although the larval head length is only a sixth that of the adolescent. The short snout is abruptly upturned, and extends beyond the feeble lower jaw. The angle of the latter is barely discernible at a point about two-thirds of the way from the mandible tip to the posterior border of the opercle. The eye is almost round, and the iris of a nearly constant width. The gape extends to the posterior part of the eye, the up-curved upper jaw having a fleshy lip and indeterminate boundaries. A few feeble, minute teeth are scattered along the maxillary and mandible. The opercular flap is well developed.

There is no trace of scales.

A shallow finfold extends over the posterior half of the distance between the snout and the dorsal origin, and a similar one on the ventral profile lies between the posterior end of the yolk sac and the anal origin.

The pectoral fins consist of minute, white, rayless pads lying on the upper anterior surface of the yolk sac. There is no trace of pelvics. The dorsal and anal are clearly marked off and in the same relative positions as in the type specimen, with the dorsal originating definitely in advance. They are, however, very low and have fewer rays (about 13 and 10 instead of 18 and 15 respectively), and these are not all distinct, though the bases of the rays are fairly well differentiated. The caudal, although still in the finfold stage,

unforked and with no trace of individual rays, is yet functionally well developed; it completely surrounds the urostyle, but extends very little beyond it, and four-fifths of its vertical development is below it.

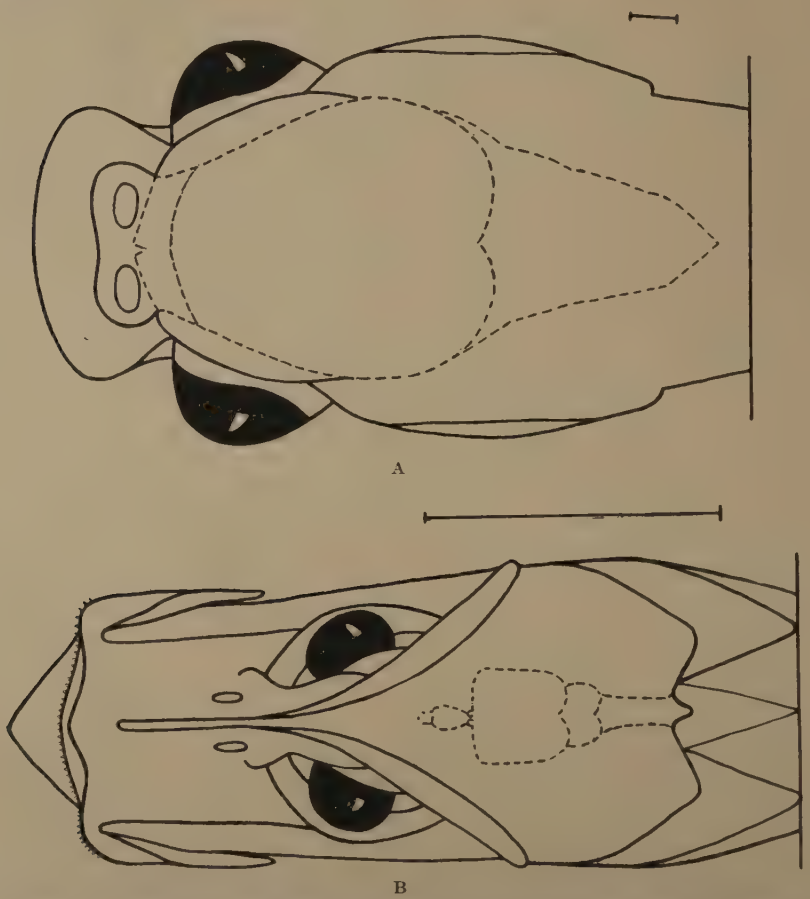


Fig. 3. *Bathytroctes drakei* Beebe. Dorsal views of head, showing position of brain in A, larva; and B, adolescent (type specimen). The relative size of the heads is indicated by the straight lines.

Comparison with Other Larvae: No. 13,470, standard length 14 mm, is at a less advanced stage than the 11.5 mm specimen just described, with a larger yolk sac and deeper finfolds. A shrinkage

in length before the transformation to the post-larval stage is thus indicated. The 10 mm specimen (No. 16,067) is very similar to that of 11.5 mm.

POST-LARVA: (Fig. 2B). The post-larval stage is briefly characterized externally by the partial development of the paired fins: The pectorals are composed of raylets instead of true rays and the pelvics are just appearing. The following specimen is a typical example:

Trawling Data: Department of Tropical Research No. 15,358; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 628; May 23, 1930; 8 miles east of Nonsuch Island, Bermuda; 600 fathoms; Standard length 16.5 mm.

Measurements and Counts: Total length 19.2 mm; standard length 16.5 mm; depth 2 (in length 8.2); head 6.3 (in length 2.6); eye, horizontal, 2.1 (in head 3); eye, vertical, 1.1 (in head 5.7); snout 2 (in head 3.1); dorsal rays 18; anal rays 14.

External Characters: In color this specimen closely resembles the type, being, when fresh, brownish gray with opercles and abdomen almost black.

The moderately compressed and elongate body tapers gradually from the shoulders to the base of the caudal. There is no trace of upturned urostyle, yolk sac or finfolds.

The head is relatively more than twice as large as in the larva, the crown considerably higher than the shoulder and sloping gradually from here to the tip of the rather long snout. The firm line of the mandible extends straight backward to its sharp angle at the vertical from the posterior part of the iris. The dorsal portion of the very elongate eye interrupts the profile of the head; the lens is set in the middle of an elliptical socket, which is so placed that the posterior part of the iris is broader than the anterior. The nostril is placed high on the snout, slightly nearer the anterior margin of the eye than the tip of the premaxillary. The well defined maxillary extends to just beyond the anterior border of the iris. Minute teeth are present in a single series on the premaxillary, maxillary and mandible in about the same numbers as in the type. There are three pairs on the vomer, and three teeth on each palatine.

There is no trace of scales.

The pectoral fin bases are fleshy pads like those of the larva, but these are now broadly fringed with raylets, though neither true

rays nor their bases are as yet distinct. The pelvics are a pair of minute, whitish projections well in front of the vertical from the dorsal origin. The dorsal, anal and caudal are relatively almost as well developed as in the adolescent type specimen, with all of the rays perfectly distinct.

Osteology: Three post-larvae, measuring 12.6 mm, 15 mm, and 15 mm respectively, have been cleared and stained, and in none is there the least trace of ossification.

ADOLESCENT: As has been said, the type specimen already described is the only example of the adolescent stage. Externally it differs most noticeably from the post-larva in the full development of the paired fins; otherwise the two stages are very similar in general contour and proportions.

SUMMARY OF DEVELOPMENT: The changes which take place during the growth of *Bathytroctes drakei* are summarized in the following tables. These results are drawn from a comparative study of all of the specimens in the collection.

Practical Summary of Changes Taking Place During Growth

Larva: 10 to 14 mm. Yolk sac well developed; jaws feeble with a few minute teeth; snout and head each very short; eyes large, but round, not horizontally elongate; caudal alone of the fins functionally well developed; pectoral a fleshy pad; pelvics invisible; moderately deep finfolds present in front of dorsal and anal; pigment well developed on trunk, absent on head and fins.

Transition: 12 mm. Yolk sac gone; jaws taking form; teeth more numerous and stronger; snout lengthening out with the jaws; head of adolescent size proportionately; no finfolds; beginning of pectoral raylets; pigment more general than in larva.

Post-larva: 13 to 19 mm. Adolescent proportions of head established: Snout and entire eye capsule each about ⅓ of head; dorsal, anal and caudal with well developed rays and proportions; pectoral and pelvic without true, countable rays, the pelvic being barely visible; pigment generally distributed, heaviest on opercles and abdomen; no ossification.

Transition: 17 to 22 mm. Paired fins with rays partially differentiated and of almost adolescent length.

Adolescent: 29 mm. Paired fins with rays entirely differentiated.

Adult: Unknown.

ORDER OF DEVELOPMENT OF PRINCIPAL EXTERNAL CHARACTERS

KEY:
. . . . . Development started.
..... Half developed.
_____ Fully developed (i. e. in regard to appearance and proportions, but not actual size, as compared with the type specimen).

	LARVA	*POST-LARVA*	*ADOLESCENT*
Number of Specimens	4	23	1
Locality	Bermuda	Bermuda	Hudson Gorge
Season	June to Sept.	May to Sept.	July
Vertical Distribution	600 to 900 F.	400 to 900 F.	800 F.
Length	10 to 14 mm	11.5 to 22 mm	29 mm
External Characters:			
Yolk sac	_____		
Profile finfolds	_____		
Heterocercal caudal fold	_____		
Homocercal caudal fin		_____	_____
Dorsal and anal fins	.....	_____	_____
Pigment	.....	_____	_____
Eye	.....	_____	_____
Snout and jaws	.....	_____	_____
Teeth	.....	_____	_____
Head length	.....	_____	_____
Pectoral fin	.....	_____	_____
Pelvic fin	.....	_____	_____

ECOLOGY

VERTICAL AND SEASONAL DISTRIBUTION: The accompanying table (Fig. 4) shows the vertical, monthly and yearly distribution of the specimens of *Bathytroctes drakei* taken off Bermuda. From the graphs (Figs. 5 and 6) it will be seen that this species was taken only between 400 and 1000 fathoms, with the majority of the specimens occurring between 600 and 900 fathoms, while the months of greatest abundance were May and September.

The table below correlates the data of the graphs just mentioned with length and growth stage (discussed under DEVELOPMENT), and gives in addition average depths and lengths:

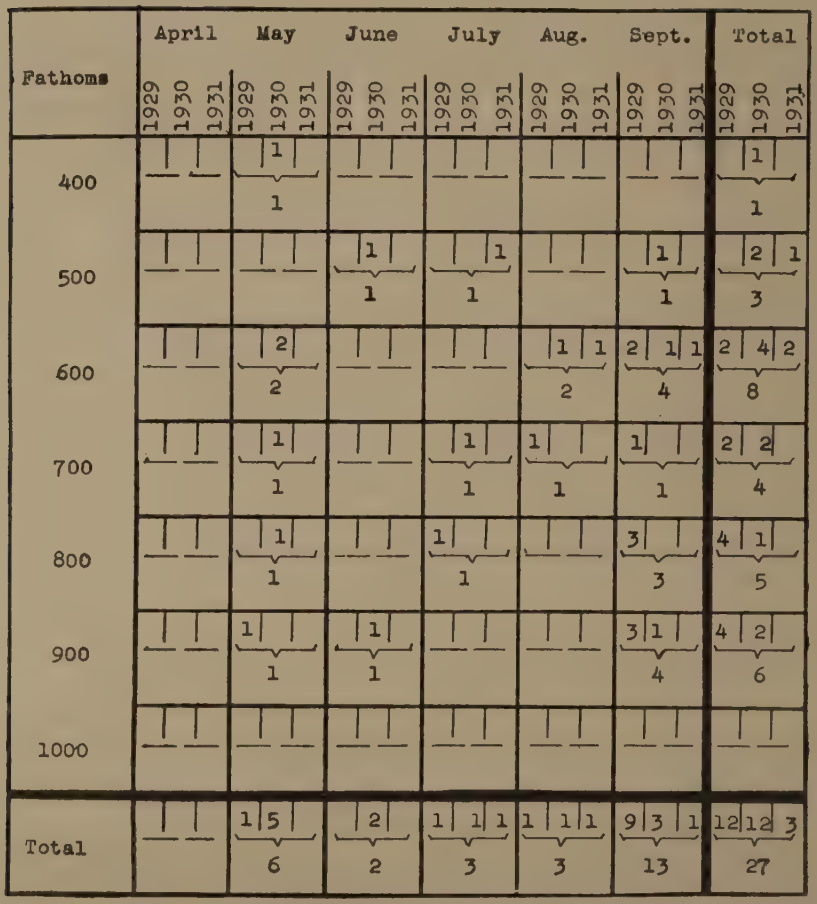


Fig. 4. *Bathytroctes drakei* Beebe. The vertical, monthly and yearly distribution of the specimens taken by the Bermuda Oceanographic Expeditions.

RELATION OF MONTH, NUMBER OF SPECIMENS, DEPTH, LENGTH AND GROWTH STAGE

Month	Number	Depth in Fath: Extremes	Depth in Fath: Average	Length in mm: Extremes	Length in mm: Average	Growth Stages
April	—	—	—	—	—	—
May	6	400–900;	667	13 to 19;	15.3	Post-larval
June	2	500–900;	700	10 to 16;	14	Larval, Post-larval
July	3	500–800;	667	12 to 20;	15.3	Post-larval
Aug.	3	600–700;	633	12 to 14;	13.3	Larval, Post-larval
Sept.	13	500–900;	738	12 to 22;	15.5	Larval, Post-larval
Total	27	400–900;	700	10 to 22;	15.2	Larval, Post-larval

From this it is seen that the average depths and lengths hold remarkably constant throughout the trawling season, showing no evident relationship. However, the number of specimens captured is too small to justify more than the most general conclusions on these subjects.

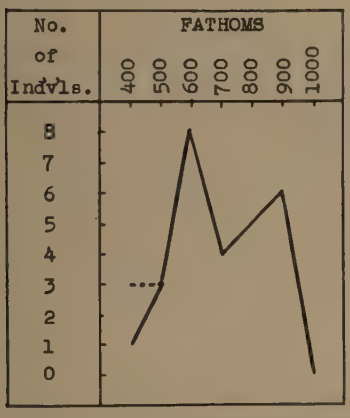


Fig. 5. (*Left*). *Bathytroctes drakei* Beebe. The vertical distribution of the specimens taken by the Bermuda Oceanographic Expeditions. The broken line is based on the number of specimens which would theoretically have been taken at 400 fathoms if as many nets had been drawn at that depth as at the others.[1]

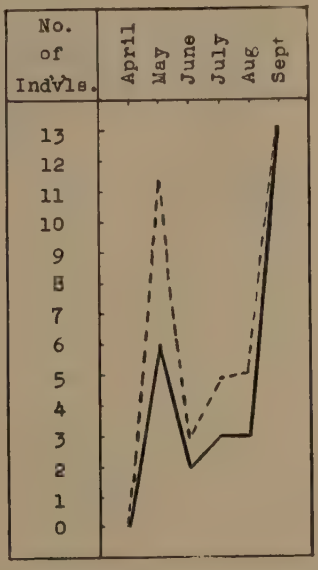


Fig. 6. (*Right*). *Bathytroctes drakei* Beebe. The seasonal distribution of the specimens taken by the Bermuda Oceanographic Expeditions. The solid line is based upon the actual number of specimens taken; the broken line upon the number which would theoretically have been caught if as many nets had been drawn every month as during September.[2]

SOCIABILITY: *Bathytroctes drakei* was always taken singly, with one exception, when two 16 mm post-larvae were found in the same net.

ABUNDANCE: Though second in order of numerical abundance among the Bermuda Alepocephalidae, *B. drakei* is less than one-third as common as *B. rostratus*, and, compared with other deep-sea fish, moderately rare. It is represented in 2.8 per cent of all of the nets drawn between 400 and 900 fathoms, the limits of its vertical distribution.

[1] See Introduction, p. 8.
[2] See Introduction, p. 7.

FOOD: The stomachs of six post-larvae, measuring from 15 to 22 mm, were opened with the following results:

15 mm	1 Copepod (length 1 mm without antenna)
16 mm	Empty
16 mm	Empty
17 mm	1 small Pteropod
19 mm	Finely digested, unrecognizable material
22 mm	Finely digested crustacean remains

STUDY MATERIAL

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Bathytroctes drakei* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described on p. 5. "Lar. Trans." indicates the Transition Stage between Larva and Post-larva. "P.-lar. Trans." indicates the Transition Stage between Post-larva and Adolescent.

No. 10,105; Net 117; 900 F.; May 18, 1929; 12.5 mm; Post-larva.
No. 11,540; Net 294; 800 F.; July 12, 1929; 14 mm; Post-larva.
No. 12,423; Net 380; 700 F.; Aug. 16, 1929; 14 mm; Post-larva.
No. 12,890a; Net 407; 900 F.; Sept. 2, 1929; 16, 16 mm; Post-larvae.
No. 12,981; Net 413; 900 F.; Sept. 3, 1929; 15 mm; Post-larva.
No. 13,047; Net 417; 600 F.; Sept. 4, 1929; 15 mm; Post-larva.
No. 13,332; Net 447; 800 F.; Sept. 9, 1929; 14 mm; Post-larva.
No. 13,470; Net 466; 700 F.; Sept. 12, 1929; 14 mm; Larva.
No. 13,762; Net 499; 800 F.; Sept. 24, 1929; 16 mm; Post-larva.
No. 13,803; Net 505; 600 F.; Sept. 25, 1929; 16 mm; Post-larva.
No. 13,843; Net 514; 800 F.; Sept. 27, 1929; 22 mm; P.-lar. Trans.
No. 14,965; Net 573; 400 F.; May 14, 1930; 19 mm; Post-larva.
No. 14,948; Net 577; 800 F.; May 14, 1930; 16 mm; Post-larva.
No. 15,349; Net 627; 600 F.; May 23, 1930; 14 mm; Post-larva.
No. 15,358; Net 628; 600 F.; May 23, 1930; 17 mm; P.-lar. Trans.
No. 15,518a; Net 647; 700 F.; May 29, 1930; 13 mm; Post-larva.
No. 16,033; Net 707; 500 F.; June 16, 1930; 16 mm; Post-larva.
No. 16,067; Net 716; 900 F.; June 17, 1930; 10 mm; Larva.
No. 17,057; Net 799; 700 F.; July 15, 1930; 20 mm; P.-lar. Trans.
No. 17,424; Net 811; 600 F.; Aug. 28, 1930; 14 mm; Post-larva.
No. 17,779; Net 838; 600 F.; Sept. 3, 1930; 12 mm; Post-larva.
No. 17,841; Net 845; 900 F.; Sept. 4, 1930; 15 mm; Post-larva.
No. 18,835; Net 916; 500 F.; Sept. 19, 1930; 15.5 mm; Post-larva.
No. 21,620; Net 1108; 500 F.; July 27, 1931; 11.5 mm; Lar. Trans.
No. 21,936; Net 1137; 600 F.; Aug. 6, 1931; 11.5 mm; Larva.
No. 23,055; Net 1255; 600 F.; Sept. 3, 1931; 14.5 mm; Post-larva.

Nos. 10,105 (KOH No. 1143), 13,047 (KOH No. 864) and 17,841 (KOH No. 1144) have been cleared and stained in order to study the skeleton.

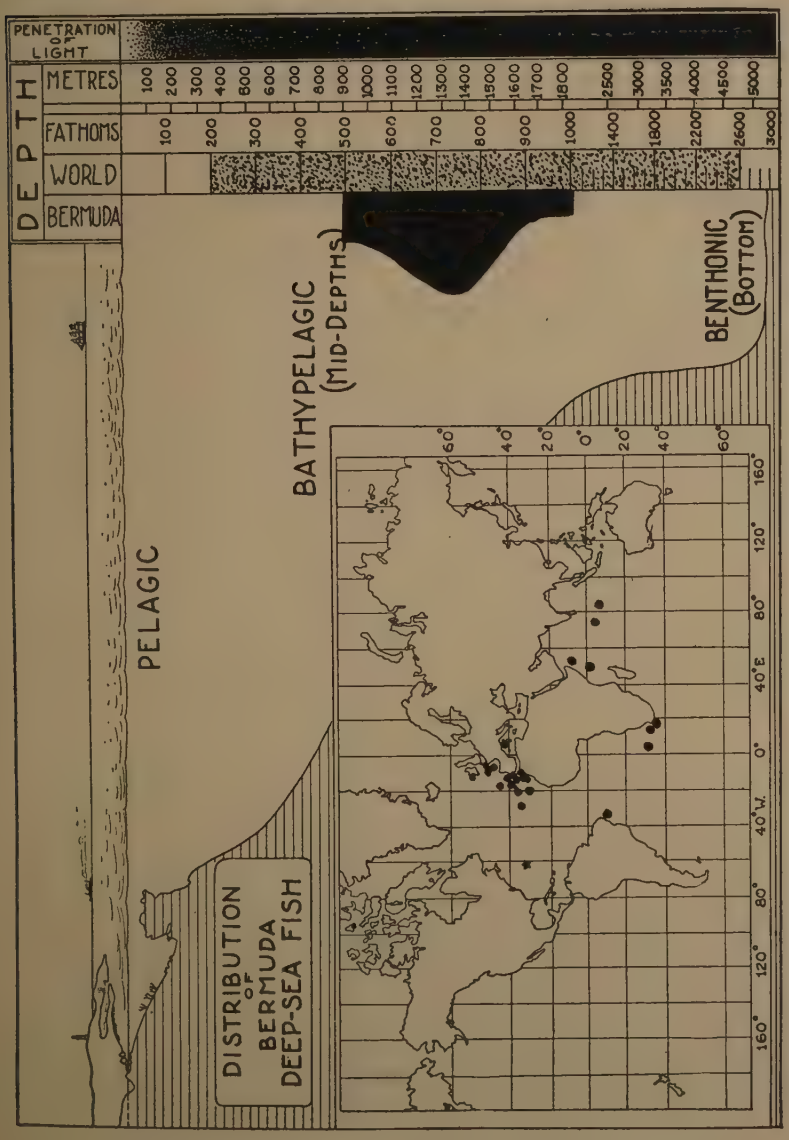


Fig. 7. *Bathytroctes rostratus* Günther. The approximate geographical and vertical distribution of all recorded specimens. The relative number of specimens taken at different depths by the Bermuda Oceanographic Expeditions is shown diagrammatically at the right, for comparison with the previously known vertical range of the species.

The following drawings are filed: B508, B868, B869, B893.

Reference

Bathytroctes drakei
Beebe 1929, p. 6. (Type description).

Bathytroctes rostratus Günther 1878

Specimens Taken by the Bermuda Oceanographic Expeditions

89 specimens; April to September, 1929 to 1931; 500 to 1000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; Standard lengths from 9.5 mm to 56 mm. First record of occurrence in western Atlantic.

Previously Recorded Specimens

About 35 specimens; 200 to 2600 fathoms; North and South Atlantic Oceans, Mediterranean Sea and Indian Ocean; Standard lengths from 9 mm to 162.5 mm. (See Fig. 7).

Adult Specific Characters

(Figs. 8E and 9d)

Bathytroctes rostratus is easily distinguished from other members of the genus by the character of the first premaxillary tooth, which is enlarged and directed almost straight forward, and by the presence of a fleshy, black, supraclavicular process immediately behind the opercle. *Color:* Grayish-brown to violet-black, head sometimes lighter; eye bluish. *Proportions:* Depth in length 4.3 to 5; head in length 3 to 4.4; eye in head 3 to 3.7; snout in head 3.7 to 3.8. *Fin Ray Counts:* Pectoral 16 or 17; pelvic 9; dorsal 17 to 20, originating in advance of anal; anal 16 or 17. *Teeth:* uniserial teeth present on premaxillary, maxillary, mandible, vomer, and, sometimes, palatine; all minute, except for premaxillary fangs; mandibular teeth smallest, and those near the symphysis are external to the lateral ones, which are set in the upper edge of the bone.

Development

The Bermuda collection of *Bathytroctes rostratus* consists of larvae, post-larvae and adolescents only, not a single adult having

been taken. The post-larvae are by far the most numerous. The relation of these growth stages to standard length and numerical abundance is shown in the following table.

THE RELATION OF GROWTH STAGE TO LENGTH AND NUMERICAL ABUNDANCE IN *Bathytroctes rostratus*

Length in mm	Larvae	Transitional Larvae	Post-larvae.	Transitional Post-larvae	Adolescents	Transitional Adolescents	Adults	Total
10–11	2	4	2					8
12–13	1	4	15					20
14–15		1	24					25
16–17			16					16
18–19			4					4
20–21			4					4
22–23			1	1				2
24–25				2				2
26–27				1				1
28–29				1	1			2
30–31				1				1
32–33					1			1
34–35								
36–37					1			1
38–39					1			1
40–41								
42–43								
44–45								
46–47								
48–49								
50–51								
52–53								
54–55								
56–57					1			1
	3	9	66	6	5			89

EGG: About 200 minute, partially developed, round, white eggs .05 mm in diameter were counted in each ovary of the largest specimen in the present collection (No. 13,081, standard length 56 mm).

LARVA: (Figs. 8A and 9a). Twelve examples of the larval

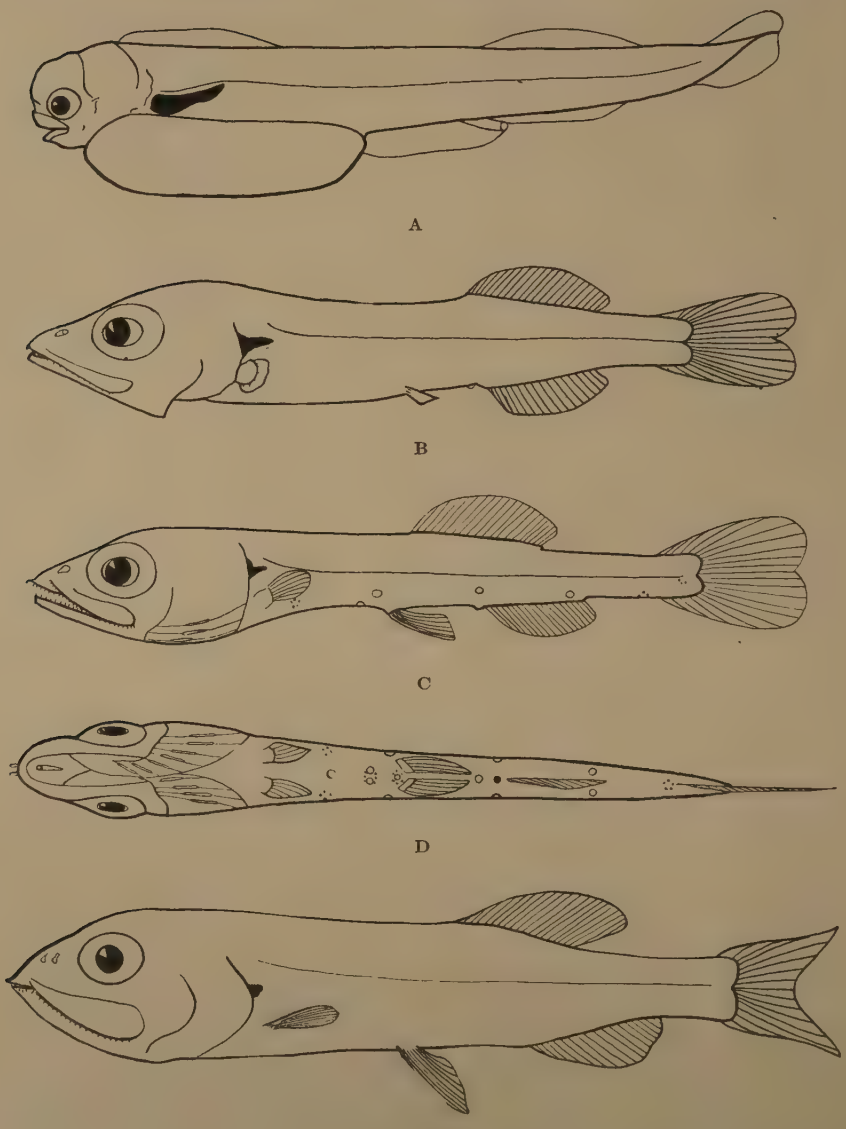


Fig. 8. *Bathytroctes rostratus* Günther. A, larva, 9.5 mm.; B, post-larva, ca. 15 mm.; C and D, adolescent, ca. 56 mm., showing photophores; E, adult, ca. 163 mm. (A, B, C and D after specimens taken by the Bermuda Oceanographic Expeditions; E, after Günther).

stage, characterized by the persistance of a yolk sac, were taken in Bermuda and measure from 9.5 mm to 14 mm. These agree well with the specimens figured by Murray and Hjort (1912, Pl. IX), except that in the Bermuda specimens there is no sign of a finfold along the middle of the back immediately in front of the future position of the dorsal fin. The youngest of the Bermuda specimens is described below.

Trawling Data: Department of Tropical Research No. 16,301; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 738; June 28, 1930; 6 miles south of Nonsuch Island, Bermuda; 800 fathoms; Standard length 9.5 mm.

Measurements and Counts: Standard length 9.5 mm; depth 1.1 (in length 8.6); head, measured to base of supraclavicular process, 1.6 (in length 5.9); eye, horizontal, .5 (in head 3.2); eye, vertical, .4 (in head 4); snout .2 (in head 8); supraclavicular process .9 (in head 1.8); length of yolk sac 3.5.

External Characters: In color the larva is light brown, except for the pale head and the dark brown, transparent-tipped, supraclavicular process.

The sub-cylindrical, elongate body is deepest (excluding the yolk sac) just anterior to the middle of the total length. Posterior to this it tapers gradually above and below to the very slender, abruptly upturned urostyle. A yolk sac of moderate size interrupts the ventral profile at the vertical from the end of the eye and extends two-thirds of the distance between this point and the anus.

The crown of the small, rounded head is scarcely higher than the level of the shoulders, and the very short, blunt snout and the mouth are directed obliquely downward, though to a lesser degree than in the slightly younger specimen figured by Murray and Hjort. The eye is obliquely set and slightly elongate, with the posterior portion of the iris much broader than the anterior. The mouth is small with a fleshy, protruding upper lip, the gape extending only to about the middle of the eye; no mandibular or maxillary angles are visible. There are no teeth. The opercula are undeveloped, leaving exposed the rudimentary gills.

There is no trace of scales. The supraclavicular process is relatively larger than at any other stage (see Fig. 9a), the anterior half attached to the skin beneath it.

On the dorsal profile a fairly deep finfold extends over the

anterior two-fifths of the distance between the nape and the vertical from the anus. Ventrally, between the end of the yolk sac and the anus, is another, the deepest on the body.

The pectoral fins are represented by minute, white, rayless pads, but the pelvics are absolutely invisible. The vertical fins are still in the form of finfolds, placed nearly opposite each other in the posterior half of the body, relatively longer than the future fins, slightly shallower than the anterior dorsal finfold, and with no sign of either fin bases or rays. The caudal, also, is in the form of a rayless finfold; it is damaged in this specimen, but in the other larvae it completely surrounds the urostyle, though extending but slightly beyond it, and is deepest ventrally.

There is no trace whatever of light organs.

Digestive System: The feeble character of the mouth and the perseverance of a well developed yolk sac in this specimen makes it probable that the larva is still drawing most of its nourishment from the yolk. The tip of the gut is visible through the posterior part of the pre-anal finfold, but does not protrude beyond it.

POST-LARVA: (Figs. 8B and 9b). The great majority of all the Bermuda specimens taken were in the post-larval stage of development, briefly characterized externally by partially developed teeth and paired fins. In all, seventy-two specimens were taken, measuring from 11 to 30 mm. Below are given descriptions of typical examples.

Trawling Data: For all characters except the skeletal system the following specimen was examined: Department of Tropical Research No. 12,890; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 407; Sept. 2, 1929; 10 miles south of Nonsuch Island, Bermuda; 900 fathoms; Standard length 15 mm.

For osteology; Department of Tropical Research Nos. 14,730 and 19,116; Cleared and Stained Collection Nos. 865 and 1146; Standard lengths 15 mm and 12.8 mm respectively.

Measurements and Counts: Total length 17.4 mm; standard length 15 mm; depth 2.4 (in length 6.3); head 4.6 (in length 3.3); eye, horizontal, 1.6 (in head 2.9); eye, vertical, 1.2 (in head 3.8); snout 1.4 (in head 3.3); dorsal rays 19; anal rays 16; supraclavicular process .7 (in head 6.6).

External Characters: The fish as a whole is dusky brown, darker than the larva, the top of the head transparent, the opercles and

abdomen blackish-brown, and the supraclavicular process black throughout its length.

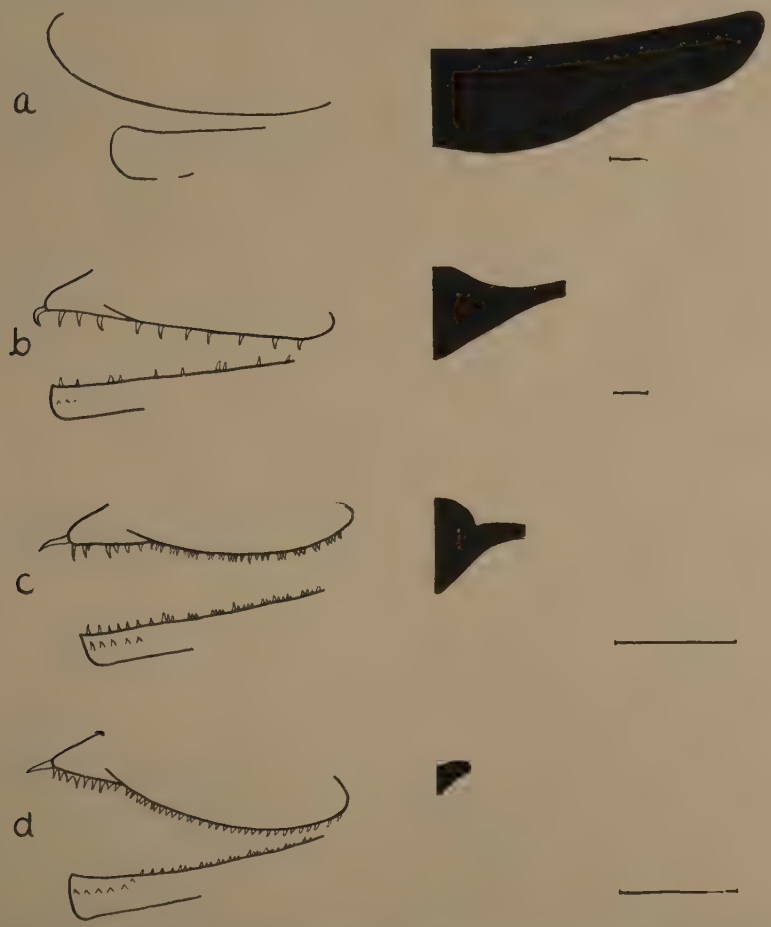


Fig. 9. *Bathytroctes rostratus* Günther. Diagram showing development of teeth and decrease in relative size of supraclavicular process with growth. The relative actual lengths of the processes are indicated by the straight lines. a, larva, 9.5 mm ; b, post-larva, 15 mm.; c, adolescent, 36 mm.; d, adult, ca. 163 mm. (a, b and c from specimens taken by the Bermuda Oceanographic Expeditions; d, after Günther's description and figure).

The body is moderately compressed and elongate, deepest at the nape, and tapering regularly from here to the caudal base. There is no trace of up-turned urostyle, yolk sac or finfolds.

The head and snout are long, relatively more than twice as large as in the larva, and slightly longer than in the adult. The crown is somewhat higher than the nape. The forehead and snout slope gently to the tip of the jaws, which are well formed, the upper protruding slightly beyond the lower. Ventrally the mandible extends downward and back in a straight line to the prominent angle of the jaw, which is behind the vertical from the posterior margin of the eye. The eyes are elongate, set obliquely in the head, the posterior portion of the iris broader than the anterior and the round lens set in the forward part of an elliptical socket. The nostrils are placed high on the snout, about midway between its tip and the anterior margin of the eye. The maxillary extends to a point halfway between the verticals from the end of the lens and the posterior margin of the iris.

The teeth (Fig. 9b) are arranged as follows in each half of the upper and lower jaws: Premaxillary 4, the most anterior slightly enlarged, curved, directed obliquely forward. Maxillary 7, widely set. Mandibular ridge about 10, smaller than those in the maxillary, more closely set, but all in a single row. On each side of the mandibular symphysis, below and outside of the series just described, are three minute, feeble teeth. On the vomer is a single pair of well developed teeth.

There is no trace of scales, though this may be due to the fact that much of the skin is missing. The supraclavicular process is free from the underlying tissues except at its base.

The pectoral fins consist of thick, white fleshy pads with a fringe of finfold-like raylets, individually indistinct. The pelvics are comparatively better developed: in a good light the bases of the individual rays are distinctly visible. Relatively they are about half as long as they are shown in the figure of the adult type specimen. The dorsal and anal are well developed, with almost as many rays as in the adult and with the ray bases, at least, individually distinct. The caudal is strongly developed, homocercal, slightly forked.

The photophore found beneath the symphysis of the lower jaw in older specimens is the only one even partially developed in the present case. It is represented by a small, round, subcuticular white spot covered with a narrow band of whitish, transparent skin which extends backwards to the junction of the mandibular ligaments.

Osteology: There is absolutely no trace of ossification in any part of either of the cleared specimens, which measure 12.8 mm and 15 mm.

Digestive System: The arrangement of the digestive organs is essentially the same as in the adolescent fish described below (Fig. 11). The following differences are, however, marked: The intestine leaves the stomach directed straight forwards and proceeds some distance before turning back upon itself, instead of curving backward at its origin; there are no coils in the region of the pelvic fin; there are no pyloric caeca; finally, the liver is proportionately smaller. The black pigment of the stomach is quite as well developed as in the older fish.

Reproductive System: The gonads are visible as two slender, whitish tubes lying the length of the coelom against its dorsal wall.

ADOLESCENT: (Figs. 8C, 8D and 9c). This stage is represented in the Bermuda collection by five specimens measuring from 28 mm to 56 mm. Intermediate between post-larva and adult, its distinguishing external characteristics are the presence of two equally developed rows of teeth in the anterior part of the mandible and a number of conspicuous light organs.

Trawling Data: All of the characters described below except those of the skeletal system are taken from the following specimen: Department of Tropical Research No. 13,081; Bermuda Oceanographic Expedition of the New York Zoological Society; Net 421; September 4, 1929; 10 miles south of Nonsuch Island, Bermuda; 1000 fathoms; Standard length 56 mm. This is the largest specimen in the collection, a female.

The observations on the skeletal system were made from Department of Tropical Research Nos. 13,467a and 16,937 (Cleared and Stained Collection Nos. 1145 and 863), measuring 32 mm and 38 mm respectively.

Measurements and Counts: Total length 64 mm; standard length 56 mm; depth 8.6 (in length 6.5); head 21 (in length 2.7); eye, horizontal, 5.6 (in head 3.7); eye, vertical, 4.6 (in head 4.6); snout 5.6 (in head 3.7); maxillary 12.4 (in head 1.7); pectoral rays 17; pelvic rays 9; dorsal rays 20; anal rays 17; supraclavicular process 2.9 (in head 7.2), measured along its dorsal margin, from edge of opercle to its most posterior tip; gill rakers in lower half of first branchial arch 13.

External Characters: In color this adolescent specimen is similar to the post-larva, except that both the brown body and the blackish brown opercles and abdomen are slightly darker. In general contour and proportions the two growth stages resemble each other closely, although in the adolescent the head is relatively a very little shorter and the eye smaller. The maxillary extends to a point immediately beyond the vertical from the posterior margin of the orbit.

The teeth (Fig. 9c) are arranged as follows: In the premaxillary the two teeth at the symphysis are well separated from each other, large, spine-like and directed straight forward, the extreme tips being slightly curved and (probably abnormally) bifurcate. These are followed on each side by a single row of seven smaller teeth, the more anterior of which have the bases considerably broader than the tips. In each side of the maxillary is a series of about 35 teeth, in a single row, some in pairs, all smaller than those on the premaxillaries, but similar in form. The mandibular teeth in each half of the jaw are in two distinct series: an inner row of about 35 teeth set in the usual position along the bony ridge of the mandible, and an outer series of 5 well developed, widely spaced teeth placed on the outer surface of the anterior part of the jaw, entirely separated from the inner series. (In the adult fish, near the symphysis, only a single outer row is present, according to the type description). The teeth of both rows are of about the same size as those in the maxillary; the anterior ones of the inner row are irregularly spaced, while posteriorly they are in close-set groups of from 2 to 6, the teeth of each group decreasing in size backwards. On the vomer is one pair of strong teeth, and one small tooth is set far back on each palatine.

No trace of scales remains. The supraclavicular process is relatively smaller than in the preceding stages.

In all of the fins the individual rays are distinct. The pelvics are obliquely inserted and extend for about two-thirds of the distance between the bases of their most anterior rays and the origin of the anal fin.

The arrangement of the light organs is in agreement with Norman's description and figures (1930, p. 268, fig. 1, and Pl. II, fig. 3). The round, photophore-like mental organ beneath the tip of the lower jaw lies in the anterior end of a shallow trough and is directed

backwards and downwards. The trough is 2.1 mm in length, narrowing posteriorly, rimmed with luminous material and covered with a transparent, convex roof of tissue which projects below the surface of the surrounding skin. It is possible that the edges of the trough can be brought together, shutting off the light completely. Of all the luminous organs, this is by far the most highly developed.

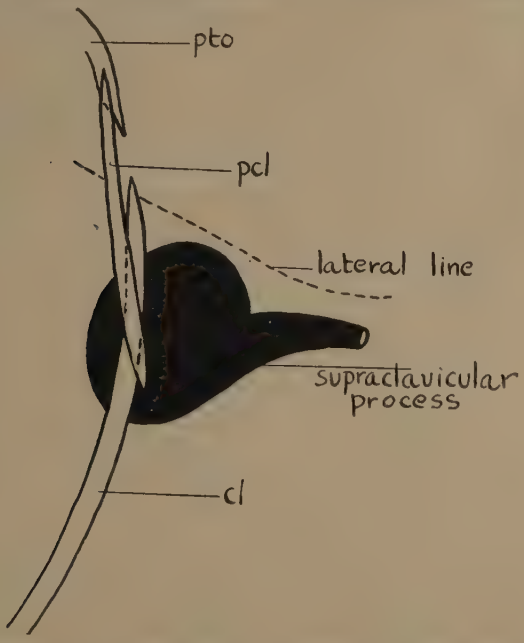


Fig. 10. *Bathytroctes rostratus* Günther. Diagram of supraclavicular process, showing its relation to pectoral girdle and lateral line. (From a cleared specimen 32 mm. in length.)

The organs of the isthmus and operculum shown in Norman's plate are found to be located on the branchiostegal rays: The most anterior three are on the left gill flap only, since this overlaps the right across the isthmus; posterior to this a single organ (which resembles an area of luminous tissue rather than a definite photophore) is found on each branchiostegal ray on both sides.

On the trunk the organs are arranged as in Norman's figure of a 47 mm fish. Those behind the pectorals and on the sides of the caudal peduncle, however, are exceedingly faint. This may be due either to damage or, as is more probable, to the fact that they are

already disappearing, since all of the light organs are supposedly absent in the adult. These faint photophores are just the ones omitted by Brauer in his plate (1906, Pl. XIII) of an 81 mm specimen. In the present example the two organs on the ventral surface immediately in front of the pelvic fins are connected by a narrow, white depression. The unpaired organ between the pelvics is not so distinct as that described by Norman, and its luminous spots seem to be on each side of it rather than before and behind it.

In cleared specimens the supraclavicular process is seen to be a retort-shaped sac, with a posteriorly directed neck terminating in a single pore. This seems to be the only opening, external or internal, to the organ, which arises just interior to the pectoral girdle at the junction of the supracleithrum and cleithrum, well below the lateral line. The posterior part of the sac and the entire neck are exterior to the body wall. It is possible that, instead of being greatly reduced in relative size in larger specimens, as is generally believed, the organ merely has a smaller part of its surface projecting exteriorly. (Figs. 9c and 10).

Osteology: In the 32 mm specimen the ossification is as a whole very slight, but is evident on the upper and lower jaws, teeth, vomer, quadrate, branchiostegal rays, gill-rakers, opercles, post-temporal, supracleithrum and cleithrum. Traces are found on the urostyle, but otherwise both the vertebral column and the fins are entirely unossified.

In the 38 mm specimen exactly the same areas are ossified, but more strongly, and in addition the parasphenoid shows a moderate degree of ossification.

The general structure of the skull closely resembles that of *Alepocephalus* (See Gregory 1933, fig. 51).

Digestive System (Fig. 11). The black, thick-walled stomach of the 56 mm. specimen is V-shaped, the apex being posteriorly directed. Its dorsal arm, from the end of the oesophagus to the apex, measures 7.8 mm; the lower arm, from apex to pylorus, 5.7 mm. Almost entirely surrounding the pylorus is a fringe of 23 short caeca. From here the whitish intestine extends straight backwards to the anus, except for one and one-half convolutions immediately in front of the pelvic fin. The liver is bi-lobed, each half extending partway up over the wall of the upper half of the stomach and the whole entirely filling the V formed by the curve of the stomach upon itself.

Reproductive System: The slender, ribbon-like ovaries extend from close behind the plane of the origin of the pectoral fin nearly to the anus. They lie flat against the dorsal wall of the coelom with a considerable space between them in the midline. The specimen

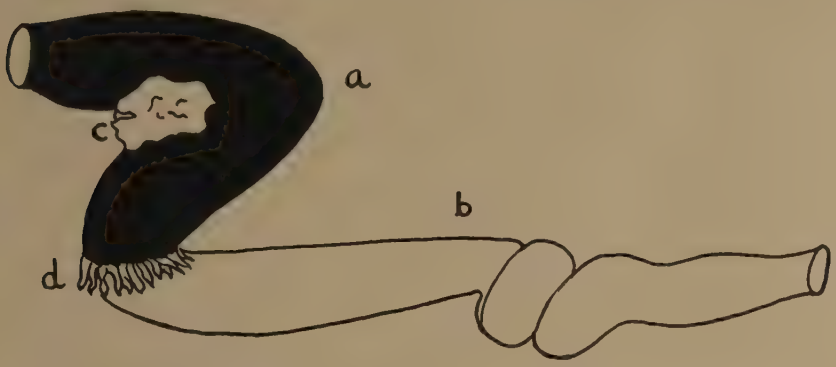


Fig. 11. *Bathytroctes rostratus* Günther. Alimentary canal, from a specimen 56 mm in length. a, stomach; b, intestine; c, liver; d, caeca.

is obviously not in breeding condition, but about 200 minute eggs can be counted in each ovary.

SUMMARY OF DEVELOPMENT: The following résumés of the characteristics of each growth stage and of the order of their development are based upon a study of all of the specimens in the Bermuda collection.

Summary of the Changes Taking Place During Growth

Larva: 9.5 to 12.6 mm. Yolk sac present; jaws feeble, toothless; snout and head very short; eyes large, slightly elongate, obliquely set; caudal alone of the fins functionally well developed and it, like the dorsal and anal, still in the finfold stage; other finfolds persisting along anterior part of back and between yolk sac and anus; a third finfold possibly present between anterior and posterior dorsal folds; pectoral a fleshy pad; pelvic invisible; external portion of supraclavicular process proportionately longer than in later stages; pigment general, moderately dense except on nearly colorless head and fins; no light organs.

Transition: 10 to 14 mm. Traces of yolk sac remaining; jaws taking form; teeth appearing, with mandibular teeth uniserial and

on bony ridge only; snout and head proportionately longer than in larva, but still shorter than in adult; remains of finfolds and external urostyle; beginning of pectoral raylets; pelvic appearing; vertical finrays appearing.

Post-larva: 11 to 23 mm. No yolk sac; adult proportions of head established, or head and snout slightly longer than in adult; outer row of mandibular teeth appearing; premaxillary fangs slightly protruding, curved throughout length; other teeth fewer than in adolescent; pectoral with raylets and developing bases; pelvic about half developed, the bases of the rays distinct in the latter part of the stage; dorsal, anal and caudal fins entirely formed, the caudal forked; supraclavicular process proportionately shorter than in larva; beginning of mental photophore; no ossification; intestine without convolutions in posterior section; no caeca; reproductive organs distinguishable, but undeveloped.

Transition: 22 to 30 mm. All fins fully developed; ossification beginning on head and caudal base; beginning of branchiostegal and trunk photophores.

Adolescent: 28 to 56 mm. Extra-mandibular rows of teeth well developed, equal to or longer than those of the inner row, all of which still persist; first premaxillary tooth greatly enlarged, directed straight forward, with the tip alone slightly curved; dorsal fin a little further forward than in adult; light organs at maximum development; ossification present only on head, cleithrum and base of caudal; intestine convoluted in posterior portion, numerous caeca present; gonads not fully developed.

(*Adult: From published descriptions.* Extra-mandibular row of teeth persist, those corresponding to them on the bony ridge, lacking; no light organs).

ORDER OF DEVELOPMENT OF PRINCIPAL CHARACTERS

KEY:

..... Development rudimentary.

----- Half developed.

_____ Fully developed (i. e. in regard to appearance and proportions, but not in actual size).

	LARVA	*POST-LARVA*	*ADOLESCENT*
Number of Specimens	12	72	5
Locality	Bermuda	Bermuda	Bermuda
Season	May, June	April to Sept.	July to Sept.

ORDER OF DEVELOPMENT OF PRINCIPAL CHARACTERS—*Continued*

	LARVA	*POST-LARVA*	*ADOLESCENT*
Vertical Distribution	500 to 800 F.	500 to 1000 F.	800 to 1000 F.
Length	9.5 to 14 mm	11 to 30 mm	28 to 56 mm
Growth Characters:			
Size of external supraclavicular process	———	.....	.....
Yolk sac	———	----	
Profile finfolds	———	----	
Heterocercal caudal fold	———	----	
Homocercal caudal fin		.....	———
Pigment	.....	———	———
Eye, size and shape	.....	———	———
Head length	.....	———	———
Snout and jaws	.....	———	———
Dorsal and anal fins	.....	———	———
Pectoral fin	.....	.....	———
Black, sac-like stomach		———	———
Pelvic fin		.....	———
Teeth		.....	———
Photophores		.....	———
Caeca			———
Intestinal convolution			———
Development of gonads			.....
Ossification of skull			.....
Ossification of cleithrum			.....
Ossification of urostyle			.....

ECOLOGY

VERTICAL AND SEASONAL DISTRIBUTION: The accompanying table (Fig. 12) shows the vertical, monthly and yearly distribution of the specimens of *Bathytroctes rostratus* taken off Bermuda. The graph (Fig. 13) indicates that the majority of the specimens were taken between 600 and 800 fathoms, with an extreme range of 500 to 1000 fathoms. On the chart of the world distribution of the species (Fig. 7) the same data are given for comparison with the vertical distribution of previously recorded specimens.

Fig. 14 shows that the months of greatest abundance were May, July and September.

A study of the following table results in the conclusion that, unlike many other deep-sea fishes, there is no relationship discernible between month, depth, and length, although the youngest fish have been taken in the spring only, while the oldest of the specimens

occurred in summer and fall. (Fig. 15 gives the same data in graph form).

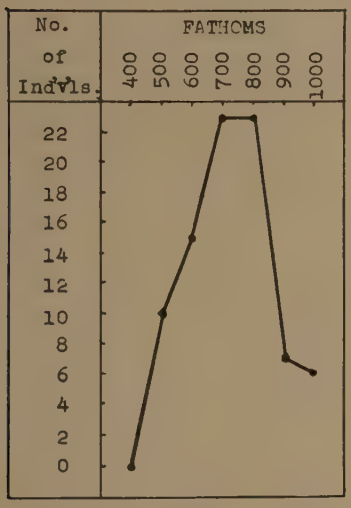
It will be noted that both the average monthly depth and the average monthly length show remarkably little variation.

Fathoms	April			May			June			July			Aug.			Sept.			Total		
	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931
400	—	—		—	—		—	—		—	—		—	—		—	—		—	—	
500	—	—		1	1		2				1				1	1	3		4	5	1
				2			2			1			1			4			10		
600	1				4		—	—		2	1	1		1	1		4		3	10	2
	1			4						4			2			4			15		
700	—	—		1	6		2		1		5				1	1	5	1	4	16	3
				7			3			5			1			7			23		
800	1			1			2	1	1	6	6		1			1	2	1	12	9	2
	1			1			4			12			1			4			23		
900	—	—			1		1			—	—				1	3	1		4	2	1
				1			1						1			4			7		
1000	1				1		3			1	3		—	—		1	1		6	5	
	1			1			3			4						2			11		
Total	3			3	13		10	1	2	9	16	1	1	1	4	7	16	2	33	47	9
	3			16			13			26			6			25			89		

Fig. 12. *Bathytroctes rostratus* Günther. The vertical, monthly and yearly distribution of the specimens taken by the Bermuda Oceanographic Expeditions.

SOCIABILITY: *Bathytroctes rostratus* does not seem to be gregarious even in the larval and post-larval stages. In the majority of cases the Bermuda specimens occurred singly in the nets, in

eight nets only were there two specimens found together, in one three and in one four. In the last case one larva was found with three young post-larvae, while in another a 13 mm fish was found with one of 21 mm and a 22 mm specimen with one of 32 mm; in



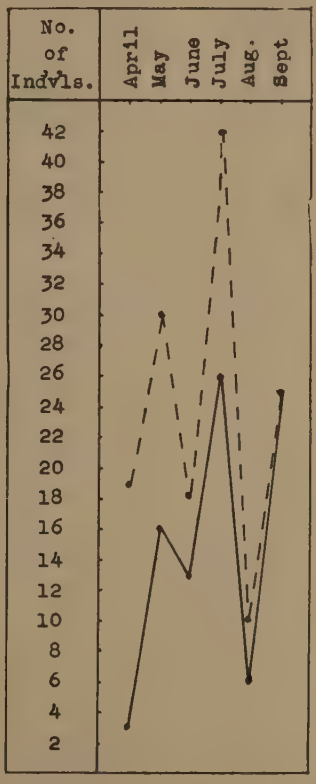


Fig. 13. (*Left*). *Bathytroctes rostratus* Günther. The vertical distribution of the specimens taken by the Bermuda Oceanographic Expeditions.

Fig. 14. (*Right*). *Bathytroctes rostratus* Günther. The seasonal distribution of the specimens taken by the Bermuda Oceanographic Expeditions. The solid line is based upon the actual number of specimens taken; the broken line upon the number which would theoretically have been caught if as many nets had been drawn every month as during September.[1]

the remaining cases the specimens appearing together were of approximately the same size and stage of development. However, it seems probable that these isolated instances of apparent sociability are accidental: It must be remembered that each net was drawn through the water for a period of four hours or more. All previously recorded specimens seem to have been taken singly.

[1] See Introduction, p. 7.

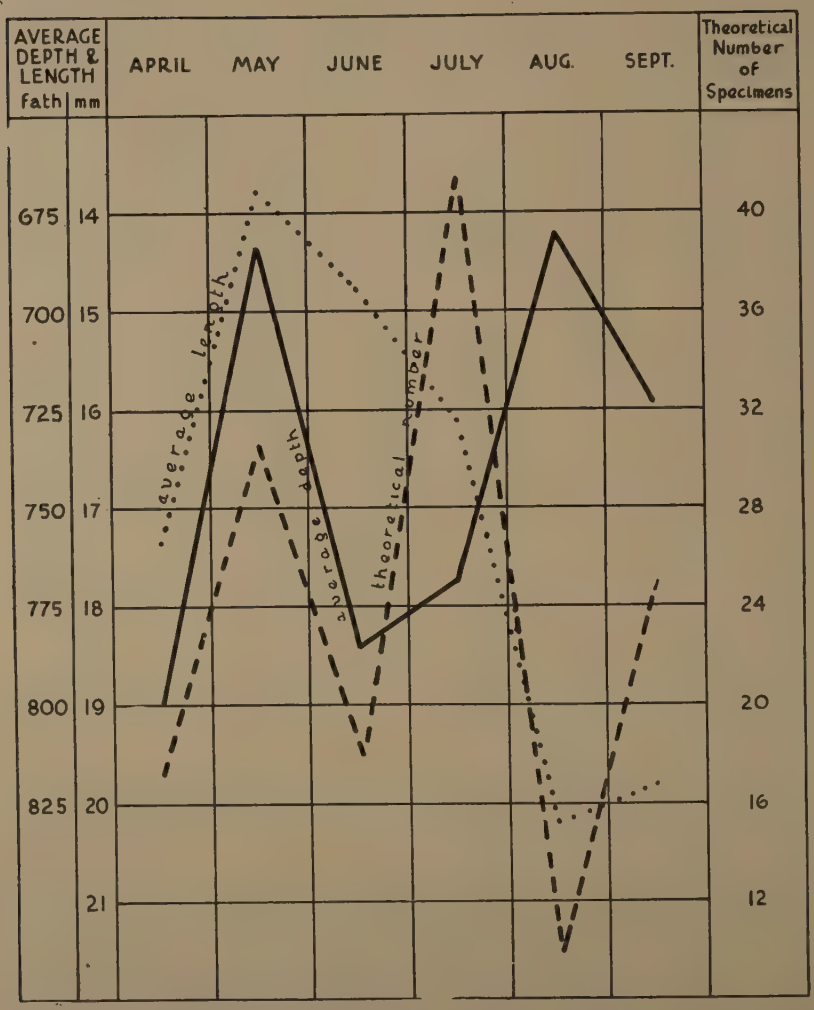


Fig. 15. *Bathytroctes rostratus* Günther. The relation of month of capture to average length (dotted line), average depth (solid line) and theoretical numerical abundance[1] (broken line), all based on the total number of specimens taken by the Bermuda Oceanographic Expeditions.

[1] See fig. 14 and Introduction. p 7.

RELATION OF MONTH, NUMBER OF SPECIMENS, DEPTH, LENGTH AND GROWTH STAGE

Month	Number	Depth in Fath.: Extremes	Average	Length in mm: Extremes	Average	Growth Stages
April	3	600–1000;	800	12 to 21;	17.3	Post-larval
May	16	500–1000;	687	10 to 25;	13.8	Larval, Post-larval
June	13	500–1000;	785	10 to 25;	14.8	Larval, Post-larval
July	26	500–1000;	769	10 to 38;	16.1	Post-larval, Adolescent
Aug.	6	500– 900;	683	14 to 36;	20.2	Post-larval, Adolescent
Sept.	25	500–1000;	724	10 to 56;	19.8	Post-larval, Adolescent
Total	89	500–1000;	739	10 to 56;	16.1	Larval, Post-larval, Adolescent

ABUNDANCE: *Bathytroctes rostratus* is uncommon among the deep sea fish taken off Bermuda. It occurred in 7.1 per cent of all of the nets drawn between 500 and 1000 fathoms, the limits of its vertical distribution in this area.

FOOD: The stomach contents of six specimens consisted entirely of the remains of crustaceans, distributed as follows:

Length of Specimen	*Contents of Stomach*	*Depth*
15 mm	1 well digested Copepod	500 Fath.
15 mm	Finely digested Crustacean	800 Fath.
17 mm	Empty	700 Fath.
25 mm	1 Copepod 1 *Sapphirina*	900 Fath.
32 mm	Empty	900 Fath.
56 mm	1 Shrimp 1 *Sapphirina* 1 Gammarid	1000 Fath.

STUDY MATERIAL

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Bathytroctes rostratus* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described on p. 5. "Lar. Trans." indicates the Transition Stage between Larva and Post-Larva. "P.-lar. Trans." indicates the Transition Stage between Post-larva and adolescent.

No. 8,827a; Net 22; 600 F.; April 15, 1929; 21 mm; Post-larva.
No. 9,576; Net 35; 800 F.; April 24, 1929; 12 mm; Post-larva.
No. 9,604; Net 44; 1000 F.; April 25, 1929; 19 mm; Post-larva.
No. 9,743; Net 60; 500 F.; May 3, 1929; 13 mm; Larva.
No. 10,102; Net 131; 800 F.; May 27, 1929; 25 mm; P.-lar. Trans.
No. 10,245; Net 136; 700 F.; May 30, 1929; 14 mm; Post-larva.
No. 10,397; Net 158; 500 F.; June 12, 1929; 14, 15 mm; Lar. Trans & Post-larva.
No. 10,426; Net 169; 1000 F.; June 14, 1929; 15, 15, 15 mm; Post-larvae.
No. 10,497; Net 174; 900 F.; June 15, 1929; 25 mm; P.-lar. Trans.
No. 10,702; Net 196; 800 F.; June 20, 1929; 17 mm; Post-larva.
No. 10,819; Net 207; 700 F.; June 22, 1929; 13, 13 mm; Post-larvae.
No. 11,135; Net 241; 800 F.; June 29, 1929; 14 mm; Post-larva.
No. 11,188; Net 245; 800 F.; July 1, 1929; 15 mm; Post-larva.
No. 11,243; Net 251; 800 F.; July 4, 1929; 15 mm; Post-larva.
No. 11,356; Net 267; 600 F.; July 8, 1929; 17, 17 mm; Post-larvae.
No. 11,385; Net 275; 800 F.; July 9, 1929; 13 mm; Post-larva.
No. 11,399; Net 277; 1000 F.; July 9, 1929; 14 mm; Post-larva.
No. 11,442; Net 281; 800 F.; July 10, 1929; 10 mm; Lar. Trans.
No. 11,868; Net 329; 800 F.; July 27, 1929; 15, 15 mm; Post-larvae.
No. 12,335; Net 375; 800 F.; Aug. 15, 1929; 36 mm; Adolescent.
No. 12,890; Net 407; 900 F.; Sept. 2, 1929; 15 mm; Post-larva.
No. 12,973; Net 412; 800 F.; Sept. 3, 1929; 21 mm; Post-larva.
No. 13,061; Net 418; 700 F.; Sept. 4, 1929; 17 mm; Post-larva.
No. 13,081; Net 421; 1000 F.; Sept. 4, 1929; 56 mm; Adolescent.
No. 13,467; Net 466; 900 F.; Sept. 12, 1929; 22, 32 mm; P.-lar. Trans. & Adolescent.
No. 13,571; Net 478; 500 F.; Sept. 20, 1929; 9.5 mm; Lar. Trans.

No. 14,723; Net 542; 900 F.; May 6, 1930; 13 mm; Post-larva.
No. 14,730; Net 539; 600 F.; May 6, 1930; 15 mm; Post-larva.
No. 14,791; Net 547; 1000 F.; May 7, 1930; 15 mm; Post-larva.
No. 14,829; Net 553; 700 F.; May 9, 1930; 12 mm; Post-larva.
No. 15,063; Net 589; 700 F.; May 17, 1930; 9.5, 11, 12, 13 mm; Larva & 3 Lar. Trans.
No. 15,204; Net 596; 600 F.; May 19, 1930; 11 mm; Post-larva.
No. 15,279; Net 618; 500 F.; May 22, 1930; 16 mm; Post-larva.
No. 15,349a; Net 627; 600 F.; May 23, 1930; 13 mm; Post-larva.
No. 15,452; Net 638; 600 F.; May 28, 1930; 12 mm; Post-larva.
No. 15,518b; Net 647; 700 F.; May 29, 1930; 15 mm; Post-larva.
No. 16,301; Net 738; 800 F.; June 28, 1930; 9.5 mm; Larva.
No. 16,442; Net 754; 700 F.; July 1, 1930; 12, 15, 16 mm; Post-larvae.
No. 16,448; Net 755; 800 F.; July 1, 1930; 11 mm; Lar. Trans.
No. 16,937; Net 757; 1000 F.; July 1, 1930; 38 mm; Adolescent.
No. 16,683; Net 759; 700 F.; July 2, 1930; 15 mm; Post-larva.
No. 16,595; Net 765; 500 F.; July 3, 1930; 17 mm; Post-larva.

No. 16,610; Net 767; 800 F.; July 3, 1930; 12, 13 mm; Lar. Trans. & Post-larva.
No. 16,657; Net 775; 1000 F.; July 4, 1930; 12 mm; Post-larvae.
No. 16,722; Net 778; 700 F.; July 5, 1930; 19 mm; Post-larva.
No. 16,873; Net 796; 1000 F.; July 9, 1930; 17 mm; Post-larva.
No. 17,010; Net 798; 600 F.; July 15, 1930; 13 mm; Post-larva.
No. 17,044; Net 800; 800 F.; July 15, 1930; 13, 21 mm; Post-larvae.
No. 17,205; Net 807; 800 F.; July 16, 1930; 28 mm; Adolescent.
No. 17,418; Net 810; 600 F.; Aug. 28, 1930; 14 mm; Post-larva.
No. 17,624; Net 830; 700 F.; Sept. 2, 1930; 19 mm; Post-larva.
No. 18,075; Net 860; 600 F.; Sept. 8, 1930; 14 mm; Post-larva.
No. 18,084; Net 861; 700 F.; Sept. 8, 1930; 16 mm; Post-larva.
No. 18,100; Net 862; 800 F.; Sept. 8, 1930; 29 mm; P.-lar. Trans.
No. 18,301; Net 866; 700 F.; Sept. 10, 1930; 16, 16 mm; Post-larvae.
No. 18,448; Net 880; 500 F.; Sept. 12, 1930; 17 mm; Post-larva.
No. 18,504; Net 884; 800 F.; Sept. 13, 1930; 14 mm; Post-larva.
No. 18,514; Net 887; 900 F.; Sept. 13, 1930; 23 mm; Post-larva.
No. 18,604; Net 890; 600 F.; Sept. 15, 1930; 17 mm; Post-larva.
No. 18,698; Net 902; 700 F.; Sept. 17, 1930; 12 mm; Post-larva.
No. 18,975; Net 921; 500 F.; Sept. 20, 1930; 30 mm; P.-lar. Trans.
No. 19,116; Net 923; 600 F.; Sept. 20, 1930; 13 mm; Lar. Trans.
No. 19,041; Net 927; 500 F.; Sept. 22, 1930; 19 mm; Post-larva.
No. 19,213; Net 933; 600 F.; Sept. 23, 1930; 15 mm; Post-larva.
No. 19,447; Net 953; 1000 F.; Sept. 26, 1930; 16 mm; Post-larva.

No. 20,554; Net 985; 700 F.; June 2, 1931; 11 mm; Post-larva.
No. 20,665; Net 1001; 800 F.; June 5, 1931; 15 mm; Post-larva.
No. 21,719; Net 1109; 600 F.; July 27, 1931; 16 mm; Post-larva.
No. 21,932; Net 1137; 600 F.; Aug. 6, 1931; 15 mm; Post-larva.
No. 21,953; Net 1139; 700 F.; Aug. 6, 1931; 26 mm; P.-lar. Trans.
No. 22,542; Net 1193; 500 F.; Aug. 18, 1931; 15 mm; Post-larva.
No. 22,717; Net 1213; 900 F.; Aug. 21, 1931; 13 mm; Post-larva.
No. 23,180; Net 1272; 700 F.; Sept. 7, 1931; 17 mm; Post-larva.
No. 23,581; Net 1316; 800 F.; Sept. 17, 1931; 20 mm; Post-larva.

Nos. 13,467a (KOH No. 1145), 14,730 (KOH No. 865), 16,937 (KOH No. 863) and 19,116 (KOH No. 1146) have been cleared and stained in order to study the skeleton. The following outline drawings are filed: B733, B733a, B870–875 incl.

Synonymy and References

Bathytroctes rostratus

Günther 1878, p. 250. (1 specimen; 6.5 in; 675 fath.; off Pernambuco; *type specimen*).

Günther 1887, p. 227, pl. LVIII, fig. 13. (Supplementary description of type specimen).

Goode and Bean 1895, p. 41. (Résumé of type description).

Koehler 1896, p. 516. (1 specimen; length questionable; 1700 m.; Bay of Biscay).

Brauer 1906, p. 17, pl. XLV, figs. 2, 3. (1 specimen; 81 mm; 2000 m.; between Cocos and Sumatra).

Holt and Byrne 1908, p. 45, pl. IV, figs. 3, 4, 5. (6 specimens; 10 to 32 mm; 650 to 1000 fath.; west coast of Ireland).

Zugmayer 1911, p. 5, pl. I, fig. 1. (7 specimens; 14 to 150 mm; 4750 (to 0) m.; Mediterranean and Coast of Portugal).

Murray and Hjort 1912, p. 394, pl. IX. (2 or more specimens; 9 to 52 mm; south of Azores and off Tangier).

Barnard 1925, p. 122. (1 specimen; ca. 165 mm (?); 700 fath.; off Cape Point, South Africa).

Norman 1930, p. 268, pl. II, fig. 3. (4 specimens; 30 to 47 mm; 350 to 1000 m.; off Cape Town).

Roule and Angel 1933, p. 6. (7 specimens; up to 155 mm; (0) to 3000 m.; Eastern Atlantic, Bay of Biscay to Madeira).

Bathytroctes proroscopus

Brauer 1902, p. 43. (5 specimens; 11.5 to 17 mm; 1500 to 2000 m.; Indian Ocean. Synonymized with *B. rostratus* by Brauer in 1906).

Genus **Dolichopteryx** Brauer 1901

GENERIC CHARACTERS: Form elongate, almost cylindrical; scales, when present, rudimentary; eyes probably always telescopic; snout long with a small mouth at the tip; teeth, when present, in either upper or lower jaw or in both; branchiostegals 2; paired fins well developed, moderately close to ventral profile; dorsal originating in front of anal, both fins short, in posterior part of body.

The character of the skull and opercles, and the structure of the jaws in particular, unquestionably place the genus among the Isospondyls, and not with the Iniomi as suggested by Roule and Angel (1930, p. 75), and I agree with Brauer (1906, p. 24–25) and Norman (1930, p. 271) that it should be included in the family *Alepocephalidae.*

NUMBER OF SPECIES; DISCUSSION OF SYNONYMY: Three species—*D. longipes* (Vaillant 1888), *D. anascopa* Brauer 1902, and *D. binocularis* Beebe 1932—have been described, of which perhaps only the first and last are valid. The table on p. 58 lists the com-

parable data available for each of the specimens of the genus which have been previously recorded, as well as for those of the present series. From this table it is apparent that both of Norman's specimens (1930, p. 271) and the 52 mm *Dolichopterygiella* of Roule and Angel (1930, p. 73; total length 58 mm) approach *D. binocularis* in their slenderness, small heads, and elongate paired fins, while the remaining specimens of the series are, allowing for differences in size, comparatively homogeneous in their greater depths and longer heads. The fact that one of the Bermuda specimens, only 35 mm in length, is not far from breeding condition and has the skeleton well ossified makes it probable that Norman is over-stressing the small size of Vaillant's and Brauer's specimens in order to explain the lack of agreement between the proportions of their fish and his. Also, the differences among the four Bermuda specimens described in the coming pages as *longipes* do not seem to be sexual. Hence the existence of still another species among the known specimens of the genus is possible, although this point cannot be decided until all of these recorded examples have been examined at one time after additional material has been secured.

In the compilation of the table it was occasionally necessary, for the sake of uniformity, to calculate the standard length and certain proportions of a specimen from the drawing accompanying the description. For example, Roule and Angel (1930, p. 69 ff) have sometimes employed the standard length and sometimes the total as the basis for their calculations of proportions.

Their 25 mm specimen (ibid. p. 70, pl. IV, fig. 90), of the *Dolichopterygiella* series is omitted from the table because, in comparison with the 23 mm Bermuda adolescent described in the present paper (Fig. 20A), it seems impossible that the former young fish can belong to the genus *Dolichopteryx*. The following are the principal objections: The specimen of Roule and Angel lacks pelvics (although they are described as present in the 8 mm specimen of the same series) while they are well developed in my fish of comparable size; similarly, telescopic eyes, a well developed anal fin and characteristically deep caudal peduncle are all found in my specimen, though lacking in the *Dolichopterygiella*. Finally, the anterior position of the dorsal fin and the shape of the snout in the drawing of the latter fish suggest that this may be, instead, a young argentinid.

GEOGRAPHICAL DISTRIBUTION: *Dolichopteryx* has been reported

THE RECORDED SPECIMENS OF *Dolichopteryx*

	Authority	Standard Length in mm	Length / Depth	Length / Head	Head / Eye	Head / Snout	Snout-Pelvic / Pelvic-Caudal	Pectoral Rays
1.	Norman 1930	120	12	4.5	?	?	3.5	14
2.	Norman 1930	100	12	4.5	?	?	2.4	14
3.	Bermuda Specimen	85	8.5	2.4	7.7	2.1	2.2	14
4.	Roule & Angel 1930	74	7.4	3.2	7	2.2	2.7	?
5.	Roule & Angel 1930	52	13	5	6.8	2.6	3.3	14–15
6.	Roule & Angel 1930	51	7.8	3.6	8	2.1	2	?
7.	Roule & Angel 1930	48	8.5	3.5	7	2	1.8	13–14
8.	Vaillant 1888	45	9	3	8	2.4	2	?
9.	Roule & Angel 1930	40	9	4	6	2	1.8	13–14
10.	Bermuda Specimen	40	9.3	3.5	6.7	2.4	2.2	13
11.	Bermuda Specimen	35.5	7.7	2.5	10	2.3	2.1	13
12.	Brauer 1906	34.8	10	3.2	6.2	2.1	1.75	14
13.	Bermuda Specimen	23	9.6	3.1	10.6	2.2	1.7	13
14.	Roule & Angel 1930	8	10	5	?	short	?	?
15.	Beebe 1932 (*D. binocularis*)	85	17	5	5.5	2.4	3.7	14

	Pelvic Rays	Dorsal Rays	Anal Rays	Eyes	Teeth	Location
1.	12	15?	12	?	Present at least in upper jaw	Off Cape Town
2.	12	15?	12	?	Present at least in upper jaw	Off Liberia
3.	9	11	10	Telescopic	Bands in upper jaw; single row in lower	Bermuda
4.	?	12	?	Telescopic	?	N. of Teneriffe
5.	8–9	15	10	Telescopic	?	Off Madeira
6.	?	11	9	Telescopic	?	Monaco Deep
7.	10	12	9	Telescopic	?	N. of Teneriffe
8.	6	5?	9+	Normal?	?	Off Morocco
9.	8	9–10	8–9	Telescopic	?	Off Funchal
10.	9	11	9	Telescopic	Bands in upper jaw; single row in lower	Bermuda
11.	11	11½	10	Telescopic	Bands in upper jaw; single row in lower	Bermuda
12.	12	10?	12	Telescopic	None	Indian O. off Cocos
13.	9	10	9	Telescopic	Bands in upper jaw; single row in lower	Bermuda
14.	present	?	?	?	?	W. of Canaries
15.	9	14	10	Telescopic	Bands in upper jaw; single row in lower	Bermuda

from the North and South Atlantic and the Indian Oceans. (Fig. 19).

VERTICAL DISTRIBUTION: The genus has been taken between 191 amd 2187 fathoms (350 and 4000 meters), the Bermuda specimens occurring between 400 and 800 fathoms (732 and 1463 meters). Between the latter depths temperatures in the trawling cylinder range between 63.1° and 40° Fah. (17.3° and 10.3° Cent.).

ABUNDANCE AND SOCIABILITY: Although only 15 specimens of this genus, including the 5 of the Bermuda series, have ever been taken, in two cases 2 specimens were caught in the same net.

VIABILITY: Not only has no *Dolichopteryx* ever been recorded as taken alive, but it is one of the most delicate of deep-sea fishes, few of the specimens having been caught in good condition.

Dolichopteryx binocularis Beebe 1932

TYPE: (Fig. 16). Department of Tropical Research No. 21,867; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1125; August 4, 1931; 14 miles south-east of Nonsuch Island, Bermuda; 400 fathoms; Standard length 85 mm.

MEASUREMENTS AND COUNTS: Total length 101 mm; standard length 85 mm; depth 5 (in length 17); head 17 (in length 5); eye diameter 3.1 (in head 5.5); snout 7.1 (in head 2.4); pectoral rays 6 + 8 = 14; pectoral length 55; pelvic rays 3 + 6 = 9; pelvic length 15; dorsal rays 15; anal rays 11; caudal rays XIII + 10 + 9 + XIII.

GENERAL DESCRIPTION: The recently caught fish as a whole appears as transparent white, with dark muzzle, five large, ventral blotches, and a midline of dark chromatophores. The upper lip is white, the jaws solidly dusky, thinning into individual, black, round chromatophores back almost to the eyes; this pigment is close over the bone of the jaws, far beneath the outer, white, transparent skin; directly below the eyes are fourteen large, purplish dendritic chromatophores, six in a straight row, the others in a bow shape below; on the side of the midbrain and back of the hind brain are solid masses of almost fused, black chromatophores; a large, triangular patch of many, very small ones over the lower angle of the gill arches; another large patch of disconnected ones directly over the heart which lies just below the pectorals; on the ventral surface are five dense patches of black showing purple glints; the fourth merges with

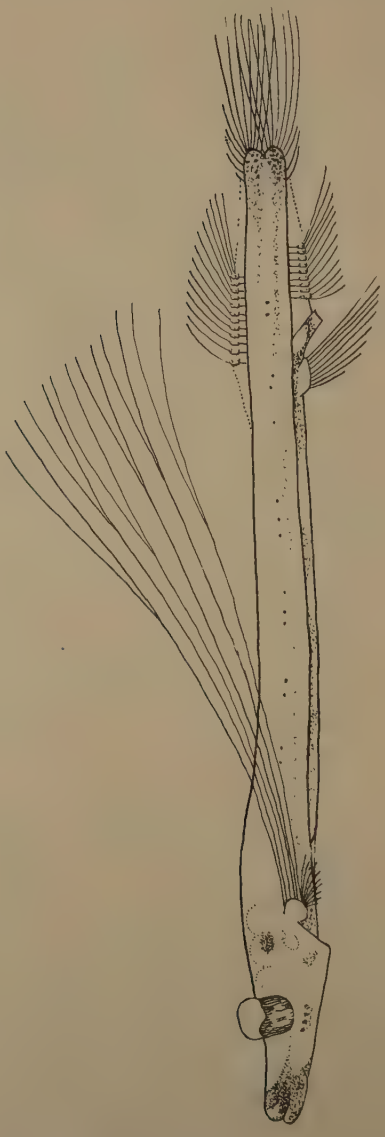


Fig. 16. *Dolichopteryx binocularis* Beebe. × 1.5.

the fifth far back beneath the ventrals; along the midline of the body a single row of iridescent or black chromatophores; these are arranged into successive groups, the more anterior of three to five chromatophores; from the midbody back the groups increase in number of components—five to ten—each group forming a short, oblique line, at a slight downward angle; midway between this line and the back is a second line of a very few, widely spread, large chromatophores, twenty-two altogether, quite irregular as regards spacing, two together or singly; from halfway between the end of the dorsal and the caudal the parallel-sided peduncle is thickly peppered with large and small, separate, dendritic chromatophores, there being a clear space along the midline.

The body is greatly elongate, almost cylindrical, with the dorsal and ventral surfaces nearly parallel. The head narrows slowly into a broad, rounded muzzle. The eyes, once and a half as high as wide, project well above the profile and are slanted forward 10° from the vertical. Separated from each other only by the narrow, spine-like forward projection of the frontal, they rest in a great depression much larger than the eyeballs themselves, the upper part covered with perfectly transparent tissue. The eye stalks are thick, short, dark, the summits clear, swollen, rounded. The eyeballs are overlaid on the front and outer side with longitudinal, prismatic, spicule scales, giving off blue, green and bronze reflections, while their bases rest in shallow saucers of silver spicules. On the outside the black of the eyeball extends upward in a rounded bay, which carries a large, pale white photophore, opening obliquely down and back in a silvery trough. The nostrils are round, close together, and about a quarter of the distance between the tip of the snout and the anterior margin of the eye. The mouth is very small, horizontal.

There is a single series of about 30 very small, close-set, incurved teeth in the mandible. In the upper jaw there are four to five rows of teeth. Externally, on the cleared, outer surface of the lips and jaw the bases of these can be distinguished as separately ossified, mosaic-like, irregularly arranged crescents or kidney-shaped bony plates. Within the jaw each of these gives rise to a long, recurved tooth, all of which teeth lie flat in a solid mass against the roof of the jaw.

In the dyed and cleared specimen a row of 58 lateral line scales

(Fig. 17) is visible extending from the opercle to the caudal, a second, incomplete row below this on the caudal peduncle and a third very short row behind the opercles.

In the first row, the first scale, just above the base of the dorsal pectoral rays, is a well-ossified, thick, half circle, opening backward. The next 26 are very small, thin, slightly ossified and irregular, some almost straight, others three-fourths of a circle. The 27th scale occurs at 18.6 mm in front of the dorsal. From here

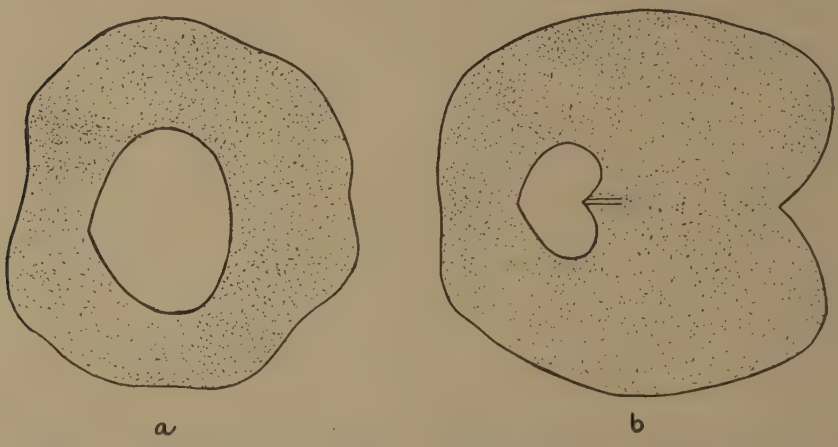


Fig. 17. *Dolichopteryx binocularis* Beebe. Scales from lateral line; a, from the vertical at origin of dorsal fin; b, from base of caudal fin. (× 58).

on the scales increase in size and thickness, and become circular. At the 40th, just over the ventral fins, they reach their largest size, the diameter keeping even for the succeeding scales to the last at the very base of the caudal. These are .86 mm in outside, vertical diameter with a central, oval opening .5 mm in length. From the 40th on, the posterior rim of the central opening shows a slight thickening of osseous tissue, which increases and concentrates toward the center until in the 51st, a slight projection is visible. In the last five this extends clear across the central hole as a knob-shaped projection, and a low spine develops on the outside.

Anteriorly the scales are five or six of their diameters apart, but they gradually approach until posteriorly the edges slightly overlap. They are placed equidistantly between the row of isolated

chromatophores, and the inferior, dense line. And now we see that each curve, or oblique row marks an individual scale, this being true even to the very first. The clear midline space in the pigmented peduncle is now explained, for it is quite filled up with the lateral line scales.

There is a second, incomplete row of scales, beginning between the 40th and 41st, and extending to the caudal. These are placed close beneath the oblique line of chromatophores, alternate with the upper row, and are much smaller, almost round and solid. These round scales are smaller anteriorly and increase slightly in size backward. There is a short row of 5 scales, similar to these, above the line of scattered chromatophores extending a short distance along the sides from the opercles. All the scales are very delicate and deciduous, a few falling off at each change of fluid in the clearing process.

The 14 rays of the pectoral are divided into two distinct groups, the upper 6 of great length, reaching to the middle of the anal, and the lower 8 only about one-fourteenth as long. The first group were, in the fresh fish, directed straight back or slightly upward, and in this individual, new-caught fish the first and sixth left rays and the first and third right rays were bent but still showed full length. They split into two about half-way of their length. The lower eight were directed obliquely downward. The rays arise from a large, fleshy, basal pad, with a sharply oblique, posterior rim. The pelvics, too, have a conspicuous base and the rays reach the base of the caudal. In the cleared tissue they are seen to be divided sharply into two divisions, six lower, very fine rays, close together, and three superior rays, placed farther apart and more than twice as stout as the others. Their insertion is well in front of the vertical from the dorsal origin, 3.7 times nearer the base of the caudal than the tip of the snout. The dorsal fin arises high above the surface of the body, from a framework supporting an oval muscle and a tall baseost for each ray except the first and last; forward the free skin stretches for a considerable distance, and posteriorly the high, free, transparent skin connects with the supracaudal spines; the anal, arising under the 12th dorsal ray, is similar, and the muscles of each fin have a scattering of black chromatophores along their sides. The caudal is slightly forked.

In addition to the orbital photophore described above, a second

luminous organ extends along the ventral surface of the body: the epidermis from the gills to the anus is loose, suspended by numerous thread-like supports, carrying an opaque band of luminous tissue; this organ gleamed only with the faintest sheen in the new caught specimen; when dyed and cleared it was found to have a large number of very small tubercles.

Osteology

Skull: (Fig. 18). The skull of *Dolichopteryx binocularis* is characterized by thin, lightly ossified bones, showing only a few foci of stronger structure, as along the dental ridge and at the quadrato-articular joint. Several elements, however, such as the preopercular, have central, high thin plates of bone, arising at right angles to the main plane. The chief specialization is the extreme antero-posterior extension of the skull, and the small, terminal mouth, recalling in a very general way, the skull ground plan of *Opisthoproctus*.

The top of the cranium shows the dominance of the fused frontals occupying fully four-fifths of the superiorly visible ossification. The cranium itself is almost completely roofed by these frontal bones. It is roughly six-sided, with the anterior aspect curving widely around the immense orbits. The forward extension of the skull is formed solely by the long, slender, almost spine-like bone of the fused frontals, which is five times the length of the cranium. On each side of this elongate bone is a prominent up-turned wing or rim, almost as if the outer edges of the frontals had been elevated to make more room for the great eyes. Beneath the same frontal rod is a transparent, median, cartilaginous septum, extending back to the vertical of the upturned eyeballs. Four-fifths of the way toward the tip of the snout, the faintly ossified prefrontals may be seen extending vaguely downward on each side of the main frontal stem. Some distance from the tip the mesethmoids appear as a very thin, overlying sheet, and through them the anterior ends of the frontals are visible, here for the first time recognizable as two slender splinters, lying side by side.

The premaxillaries form a broad bony lip about the mouth and the superior ends of the maxillaries are seen, sloping steeply downward and back.

The second largest bones of the cranium are the pterotics, long, irregular oblongs, separated by a well-marked open suture from the

whole lateral aspect of the frontals. At their anterior ends arise small, angular sphenotics, taking a small share in the bounding of the orbits. The parietals, equal to the sphenotics in size, are ill-defined, but lie between the postero-lateral curve of the frontals and the pterotics. The supra-occipital shows a small, rounded base, and a posteriorly directed spine. The epiotics are not nearly as well defined as some of the other bones, but project from the postero-lateral cranial profile, as two rounded lobes. Over them extend the elongate post-temporals, forming a close, overlapping joint with the supra-cleithra.

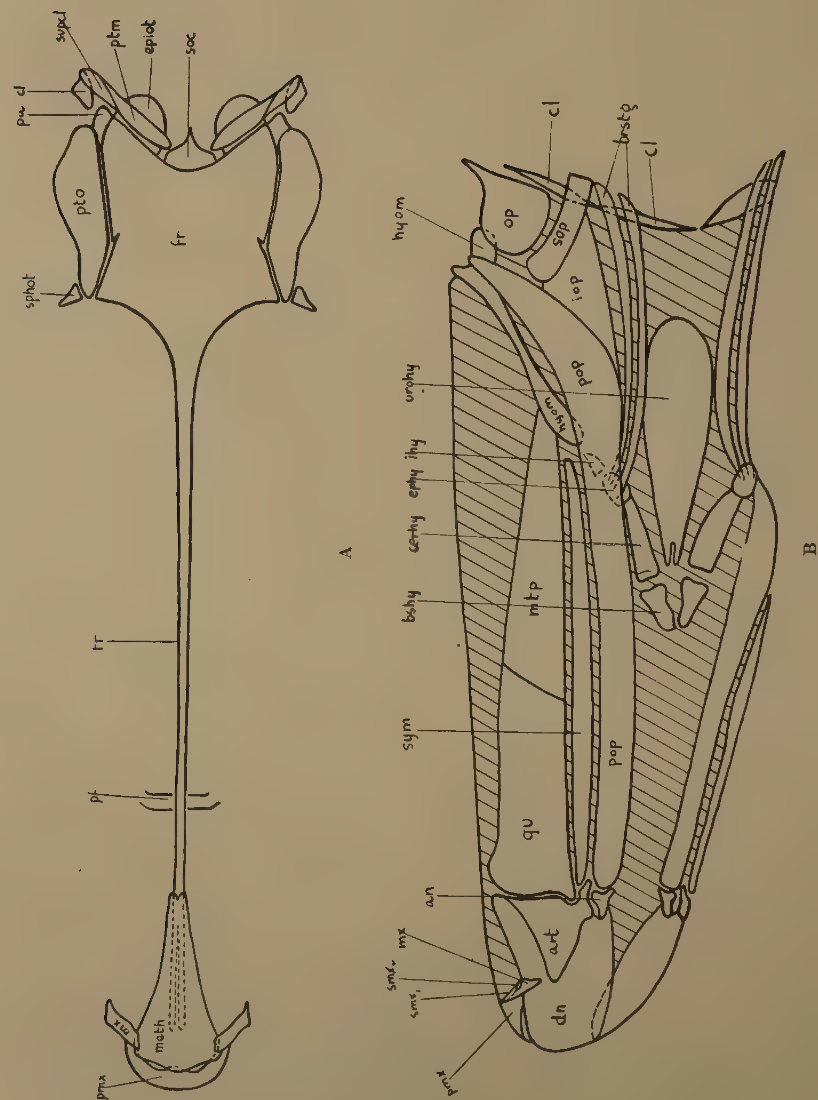
The lateral view of the skull shows all the above bones in clearer relationship, the pterotic nearly vertical, and bordering the whole lateral cranium. Beneath it is a small, unidentified, crescentic ossification in the midst of a large, irregular, unossified area.

A long, slender parasphenoid, similar in diameter to the elongate frontal spine, bounds the enormous optic lobes, extending from mid-mesethmoid backward in an easy double curve, and disappearing behind the hyomandibular. The prefrontal is seen to be fairly well ossified, but with vanishing ends above and below.

Palato-Pterygoid Arcade: The hyomandibular, like all the bones, is almost transparent and only by careful lighting and focusing can be satisfactorily differentiated from the partly overlying preopercle. It is shaped roughly like a mammalian femur, with large, superior, rounded, double heads, one extending interior to the sphenotic and pterotic, and the other holding the same relation to the upper, anterior rim of the opercle. The shaft of the hyomandibular extends forward and downward and makes three contacts, one with the metempterygoid, one with the symplectic and one with the interhyal. The symplectic is a long, slender rod reaching far forward, ventral to the metempterygoid and quadrate, almost to the hinge of the jaw.

Jaw Apparatus: The jaw bones are well ossified. The premaxillaries are separated medially by the slightest of sutures. Their posterior ends disappear beneath the maxillaries, which cross them at an oblique downward and back angle. The mid-posterior portions of these bones are occupied by two supra-maxillaries. The teeth have been described elsewhere.

The mandible is heavy and deep, the upper profile straight, and the posterior almost so. The articular is faintly separated,


A
B

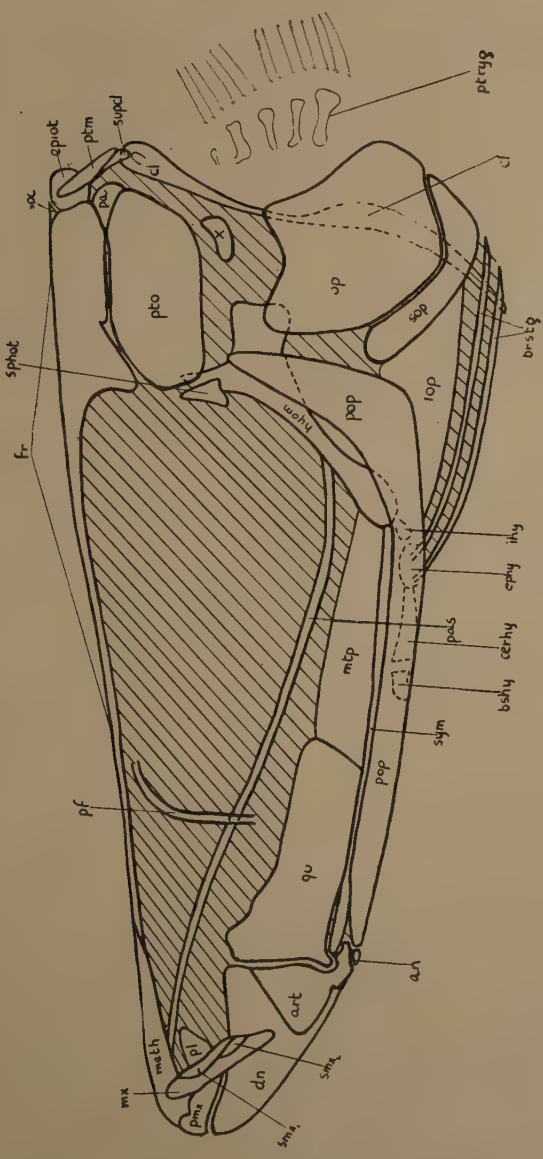


Fig. 18. *Dolichopteryx binocularis* Beebe. Skull, hyoid arch and opercular bones. A, dorsal view; B, latero-ventral view; C, lateral view.

comprising one-third of the infero-posterior area; the angular is small, very irregular and wholly ventral to the quadrate articulation.

OPERCULAR BONES: The opercles, thin as they are, are solid to their boundaries, and show none of the posterior comb-like structures so conspicuous in *Alepocephalus* and *Bathylagus*.

The opercle is irregularly circular, and is bounded on the upper and anterior faces by wide, unossified areas. Along the lower curves, the subopercle fits closely, the latter bone being roughly L-shaped. The preopercle begins exterior to the upper end of the hyomandibular and passes down over that bone, then bends abruptly forward, and extends as a wide heavy shaft almost to the angular, its anterior end actually excavated to fit loosely the posterior face of the angular. The interopercle is a broad triangle fitting ventral to and between the preopercle and subopercle.

HYOID ARCH: (Fig. 18B). A small interhyal connects the hyomandibular with the epihyal. The latter is twice the size of the interhyal, and from it arise two strong branchiostegals, extending in a flat curve back close along the lower profiles of the interopercle and subopercle.

The ceratohyal is a stout bone, three times as long as the epihyal, ossified only in its median portion, although its entire profile is visible, especially anteriorly where it articulates with the basihyals. These almost merge in the midline, the opposing surfaces mutually corrugated as if they articulated.

In the mid-line of the throat lies the large urohyal, its bifurcated anterior tip close to the ceratohyals, and its broad, rounded, posterior end extending half-way the whole length of the branchiostegals.

PECTORAL GIRDLE: The supra-cleithrum extends only very slightly beyond the inferior end of the post-temporal. With it articulates the broad, rounded end of the cleithrum, which thence extends, now enlarging, now contracting in profile, down, and slightly forward, interior to the posterior third of the opercle and ending beneath the subopercle.

VERTEBRAL COLUMN: The clearing was stopped before the body tissues became transparent, so I can see little of the vertebrae. Anteriorly they are fairly well ossified, but posteriorly, at least from the rear end of the dorsal fin, they are nearly transparent, and here considerably enlarged in diameter, up to the very last. The urostyle is very strongly ossified, and extends as a straight rod,

from the end of the column, obliquely up to the surface of the upper profile of the very deep peduncle, pushing its head between the bases of the most posterior, upper, caudal spine.

FINS: The rays of all the fins, both vertical and paired, are very strongly ossified, the pterygials and baseosts less so.

The pectoral pad shows four well developed pterygials, with broadened distal ends. These four expanded heads are more or less closely connected with the second, third and fourth; fifth, sixth and seventh; eighth, ninth and tenth; and eleventh, twelfth, thirteenth and fourteenth finrays respectively. There is a faint, but distinctly ossified, fifth pterygial element near the upper part of the fin.

The fifteen dorsal rays show twelve baseosts, the anterior and posterior rays lacking them. The second and third show a single, high, thickened, anteriorly directed bone. The first ray is very short and the two lateral bases are not joined, standing erect as two short, curved, erect spines.

Of the eleven anal rays, only eight have ossified baseosts, the two anterior and the posterior ray lacking bony supports.

The typical, segmented caudal rays are 19 in number; 10 in the upper half and 9 below, with the two central rays well separated. Above and below the peduncle are 13 unsegmented caudal "spines." On the upper profile, the last of the spines is clamped over the end of the urostyle, while the succeeding three pairs are in intimate contact with three, long, flat, separate, neural spines.

DISCUSSION

A direct comparison between the characteristics of *D. binocularis* and those of all the other known specimens of *Dolichopteryx* may be made from the table on p. 58. Differing from all of the others in its great slenderness, *D. binocularis* approaches most closely the 58 mm specimen of Roule and Angel (1930 p. 73, pl. IV, figs. 94 and 95), described as a *Dolichopterygiella.* Even this latter specimen, however is comparatively deep (depth 14 in total length, not 20, as in *D. binocularis*) and has the pectoral rays perfectly graduated in length instead of divided into two unequal groups.

STUDY MATERIAL

The type is in the collections of the Department of Tropical Research of the New York Zoological Society. It has been cleared and stained as KOH No. 960.

The following material has been filed: Colored plate B827; outline drawings B828, B828a, B889, B890, B891, B892; photographs 6160-L and 6307-L.

The figure of *D. binocularis* has been redrawn, as that in Zoologica, vol. XIII, no. 4, p. 48 was found to be inaccurate in several respects.

Dolichopteryx longipes (Vaillant 1888)

Specimens taken by the Bermuda Oceanographic Expeditions

4 specimens; June to September; 1929 and 1930; 600 to 800 fathoms; from a cylinder of water 8 miles in diameter (5 to 13) miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat.; 64° 36′ W. Long.; Standard lengths from 23 to 85 mm.

Previously Recorded Specimens

4 specimens; 191 to 2187 fathoms; Atlantic and Indian Oceans; Standard lengths from 35 to 120 mm. (Fig. 19).

Specific Characters

Whether or not all of the specimens synonymized by Norman (1930, p. 271) with *Dolichopteryx longipes* and those described by Roule and Angel (1930 p. 69 ff) under the heading *Dolichopterygiella* prove eventually to be of the same species and identical with the present series, all are distinguished at once from *D. binocularis* Beebe 1932 by the relative thickness of the body (depth in standard length 7.7 to 13 instead of 17). The following measurements and counts are applicable to all the known specimens of the genus except *D. binocularis: Color:* White, sometimes with black chromatophores on head and trunk and several pairs of ventral subdermal spots. *Proportions:* Depth in length 7.4 to 13; head in length 2.4 to 5; eye in head 6 to 10.6; snout in head 2 to 2.6; distance from pelvic to caudal base in distance from snout to pelvic 1.75 to 3.5. *Finray Counts:* Pectoral 13 to 14; pelvic 6 to 12; dorsal 5 to 15; anal 8 to 12. *Teeth:* In all specimens where teeth have been noted, they are minute, arranged in bands in upper jaw and in a single row in the lower. (See also the table on p. 58 and discussion on p. 56).

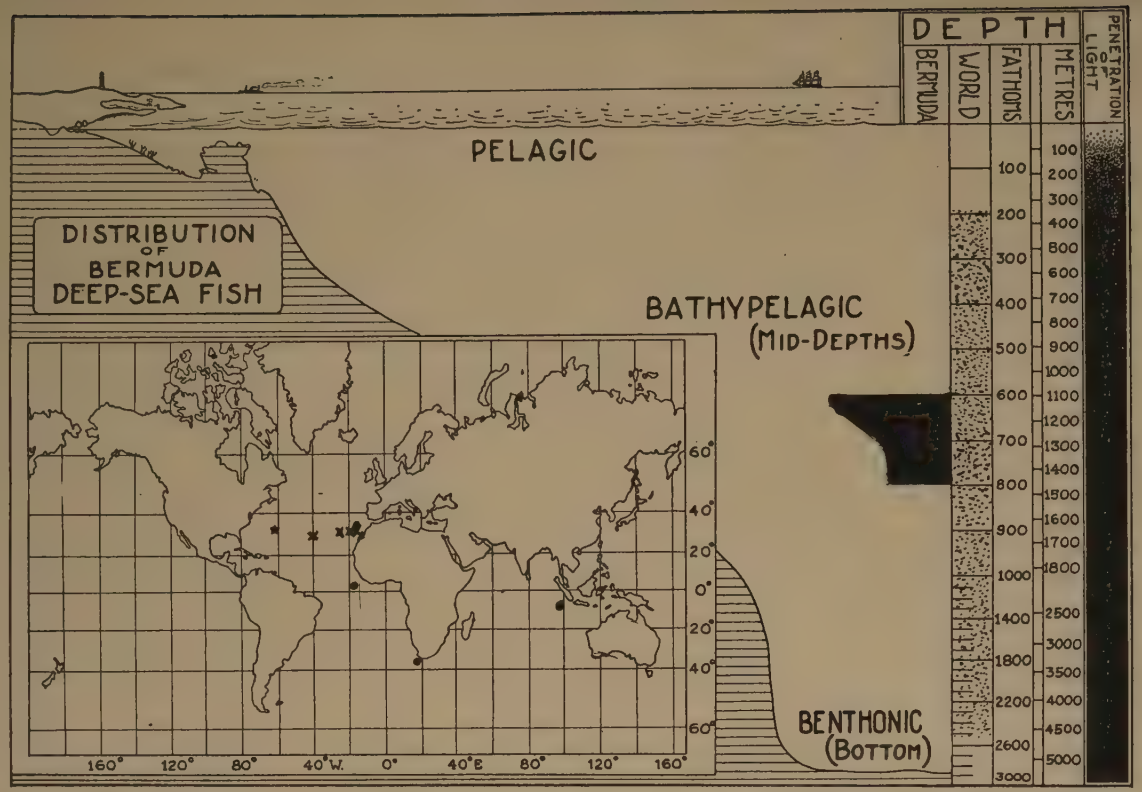


Fig. 19. *Dolichopteryx* Brauer. The approximate geographical and vertical distribution of all recorded specimens of the genus. The dots indicate where *D. longipes* has been taken, the crosses, *Dolichopterygiella* of Roule and Angel. Bermuda, where both *D. longipes* and the type of *D. binocularis* were taken, is marked by a star. The relative number of specimens taken at different depths by the Bermuda Oceanographic Expeditions is shown diagrammatically at the right, for comparison with the previously known vertical range of the genus.

Development

Egg: The 100 well developed eggs found in each ovary of an 85 mm female (No. 13,062a) are round, white (after three years in preservative) and .2 mm in diameter. These are located in the middle and posterior parts of the ovaries only. In the anterior portions and between the white eggs are at least six times as many smaller, yellowish, translucent, undeveloped eggs, which gives an estimated total of 1400 eggs in both ovaries.

Larva and Post-Larva: No example of either of these stages has been taken by the Bermuda Oceanographic Expeditions.

Adolescent: (Fig. 20A). Due to lack of material for comparison, it is impossible to be sure whether the single 23 mm specimen in the present collection is in the post-larval or adolescent stage. However, taking as criteria the differentiation of the fin rays and the development of the teeth, as well as the high degree of ossification of a cleared and dyed example from the same net which is but 12 mm longer, the 23 mm specimen is probably adolescent.

Trawling Data: Department of Tropical Research No. 8827a; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 22; April 15, 1929; 9 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 23 mm.

Measurements and Counts: Total length 26.1 mm; standard length 23 mm; depth 2.4 (in length 9.6); head 7.4 (in length 3.1); eye .7 (in head 10.6); snout 3.3 (in head 2.2); pectoral rays 13; pectoral length 2.3 (broken off); pelvic rays 9?; pelvic length 2.3; dorsal rays 10?; anal rays 9?; caudal rays IX+10+10+IX.

External Characters: In general color the fish is white, with faint black chromatophores around the mouth, in a line along the maxillary, on the crown of the head, at the base of the pelvic and at the extreme base of the caudal fin. The top of the head and snout is almost transparent. Through the tissues of the ventral surface five pairs of good sized, dendritic chromatophores are visible lying along the intestine. The skin of the trunk is entirely missing, so that the superficial markings of this region are unknown.

The body is almost cylindrical and moderately elongate, tapering but slightly from the shoulders to the base of the caudal fin. The bases of both paired and vertical fins are conspicuously elevated.

The crown of the fairly large head is little elevated above the

level of the nape; from here the forehead and elongate snout slope gradually to the tiny, terminal mouth. The lower jaw slants downward and back to its angle at a point but two-fifths of the distance between the tip of the snout and the vertical from the anterior margin of the eye. Posterior to this the ventral profile of the head is unbroken and perfectly horizontal. The eye is directed straight upwards with the entire external portion of the lens projecting above the level of the interorbital profile. Minute teeth are present in

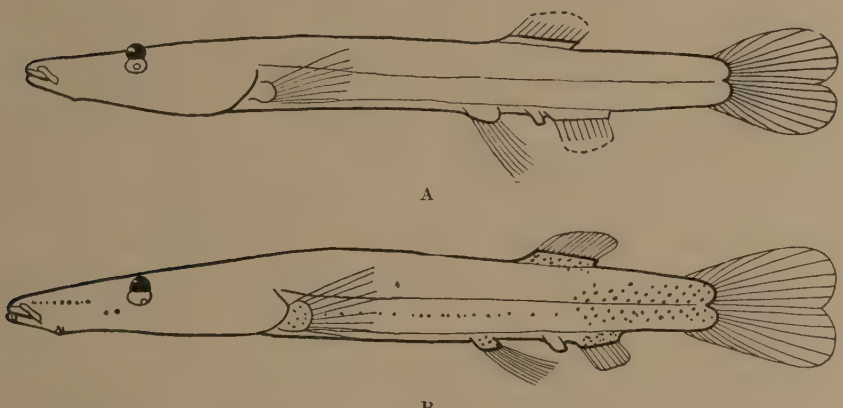


Fig. 20. *Dolichopteryx longipes* (Vaillant). A, adolescent, 23 mm.; B, young adult male, 35.5 mm.

the premaxillary, maxillary and mandible, those in the upper jaw being at least biserial. The gill openings are moderate, with their upper boundary at a point half the distance between the ventral and dorsal profiles.

The pectoral rays arise from well developed pads and show no division into groups; they reach but one-fourth of the distance between their base and that of the pelvics, but have evidently been broken off. The pelvics likewise are undivided, and extend to beyond the anal origin. They are 2.6 times as far from the origin of the snout as from the caudal base, and the base of the first ray is 1.1 mm in front of the vertical from the dorsal origin. The anal commences under the middle of the dorsal. Between the most posterior of the feebly developed, dorsal, caudal raylets and the first of the stout, terminal, true caudal rays is the projecting tip of the urostyle. The rays of all of the fins are double.

The large photophore found on the iris of older specimens is represented only by a pale-colored bulge near the orbital margin.

ADULT: The three remaining specimens in the collection consist of one young male (35.5 mm), one young femle (40 mm) and one mature female (85 mm). Descriptions of all three follow.

YOUNG MALE: (Fig. 20B). *Trawling Data:* Department of Tropical Research No. 8827; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 22; April 15, 1929; 9 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 35.5 mm.

Measurements and Counts: Total length 40.5 mm; standard length 35.5 mm; depth 4.6 (in length 7.7); head 14 (in length 2.5); eye 1.4 (in head 10); snout 6.2 (in head 2.3); pectoral rays 13; pectoral length 4.3; pelvic rays 11; pelvic length 6.4; dorsal rays 11½; anal rays 10; caudal rays XI+10+10+IX.

External Characters: The entire fish is white marked with chromatophores distributed as follows: A close-set line of black ones on each side of the mandible and isthmus; a broad band of brown pigment, visible through the tissues of the snout, on the roof of the mouth extending from the inner series of teeth to almost three-quarters of the distance between the tip of the snout and the anterior margin of the eye; two single, black spots on the cheek, below and in front of the eye; a series of black chromatophores above the lateral line, and a similar one below it, from pectoral to caudal base. Due probably to the damaged condition of the skin, these are nearly obliterated in the anterior part of the fish, but posterior to the pelvic fin each series is seen to be composed of oblique rows of chromatophores, one row to each myomere and two or three chromatophores in each row. Each pigment spot consists of a small, dark, central nucleus in the center of a lightly pigmented disc. The border of the latter is usually darker, giving a definitely bounded, ringed appearance. At the base of the caudal fin the chromatophores are smaller, and a few of them are dendritic. Here the linear formation is lost, there being simply two clusters of the dots, one above and one below the lateral line. The bases of all the fins are similarly pigmented. At least five pairs of subdermal, abdominal spots are faintly visible between the pectoral base and the anal origin. In the same area the wall of the coelom shows brown through the abdominal tissues, from a fusion of densely scattered, dendritic chromatophores. Iris black. Iris photophore bronze.

This specimen is relatively deeper, and has a larger head than any of the other specimens. Otherwise it is of typical *Dolichopteryx* contour, being almost cylindrical, tapering but slightly and having the fin bases elevated. The perfectly telescopic eyes do not extend to the height of the bony interorbital ridge. The maxillary reaches to a point about a third of the distance between the tip of the snout and the vertical from the anterior border of the eye.

In the premaxillary are about two rows of minute teeth. In the anterior part of the maxillary they are also biserial, but become single posteriorly; in size all are about equal to those of the premaxillary. There are about thirty teeth in each half of the mandible in a single row. These are very small and close-set in the anterior four-fifths of the jaw, being but one-third the size of those in the maxillary; the most posterior six or seven, however, become rapidly larger, approaching in size those of the upper jaw.

There is no trace of scales anywhere on the body.

The longest pectoral rays, which are probably broken, extend slightly more than half-way between their base and that of the pelvics. The rays of the latter reach to mid-anal. The upper four or five pectoral rays are slightly separated from the lower ones, but the pelvics are quite undivided. Inserted only 2.1 times as distant from the tip of the snout as from the caudal base, they are located slightly farther forward than in any of the other Bermuda specimens; between the pelvic base and the vertical from the dorsal origin is 2.4 mm. The anal originates under the last dorsal ray. The tip of the urostyle is invisible externally.

There is a moderate sized, semicircular photophore on the outside of the eyeball, directed straight inward. No trace is found of the ventral band of luminous tissue found in *D. binocularis.*

Osteology: In the head the jaws, teeth, frontal, parasphenoid, quadrate, metethmoid and opercles are all strongly ossified, and in arrangement and form are closely similar to those of *D. binocularis.* In the vertebral column are 43 vertebrae plus urostyle. The anterior vertebrae are rather small (.75 mm in diameter at neck), becoming considerably larger at mid-body, reaching their maximum size just in front of the dorsal (1.1 mm in diameter) and continuing very deep clear to the caudal. The entire column is well ossified, with the exception of the 40th and 41st vertebrae. In these the lower halves are almost unossified, the upper halves entirely so. The

urostyle, which terminates between the bases of the most posterior of the dorsal caudal raylets and the first true caudal rays, is also strongly ossified, though the hypurals and epurals show no trace. The cleithrum and supra-cleithrum are both strongly ossified; the pelvic girdle, very slightly, except that the long, pelvic bone shows a considerable amount of ossification throughout the distal half. All of the fin rays are well ossified, their baseosts very slightly.

Digestive System: (Fig. 21). All of the digestive organs are white. The stomach (7.3 mm) is an elongate, blind sac, not much broader than the oesophagus. The intestine, less than twice as

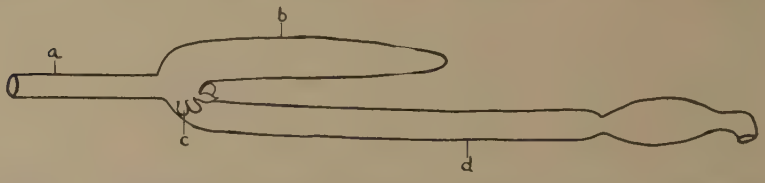


Fig. 21. *Dolichopteryx longipes* (Vaillant). Alimentary canal. a, oesophagus; b, stomach; c, caeca; d, intestine.

long (14 mm) opens from it at its anterior end, and extends straight backward to the level of the pelvic fins. Here there is an abrupt constriction followed by a short swelling, which narrows again just before reaching the anal papilla. The liver lies far forward against the oesophagus, just behind the .6 mm heart (auricle and ventricle) and measures 1.7 mm in length. The pyloric region is damaged, but there seem to have been several caeca.

Reproductive System: But one testicle is present, due to damage to the specimen. This lies on the left side, outside of the liver, beginning at the level of its posterior half. It is short and broad, measuring 1.9 mm in length. There is a minute sperm duct.

YOUNG FEMALE: *Trawling Data:* Department of Tropical Research No. 18,400; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 862; Sept. 8, 1930; 9 miles south-east of Nonsuch Island, Bermuda; 800 fathoms; Standard length 40 mm.

Measurements and Counts: Total length 46.2 mm; standard length 40 mm; depth 4.3 (in length 9.3); head 11.4 (in length 3.5); eye 1.7 (in head 6.7); height of eye 2.1; snout 4.7 (in head 2.4); pectoral rays 13; pectoral length 5; pelvic rays 9; pelvic length 10.7; dorsal rays 11; anal rays 9; caudal rays XIV+10+10+XI.

External Characters: The following color notes were made from the fresh specimen: General color translucent white; much of the upper, anterior half of the head transparent covered with very thin tissue, over which extend 5 or 6 oblique, nerve threads; the white brain, well back of the eye, is quite isolated in this transparent area; base of eye glittering steel blue; a dense sprinkling of round, black, chromatophores about the jaws. Trunk chromatophores: An enormous, dark, dendritic chromatophore covers the outer part of the pad of the pectoral base; eight large, irregular chromatophores, as large as the pectoral one, are arranged along the side of the body; from the base of the pectoral back along the lower part of the side to the caudal base runs a line of very fine, glittering, greenish-black shreds of pigment, first as a continuous line, then, posteriorly, as a series of irregular, oblique lines, of 5 to 9 dots each; at the base of the caudal a rather thick scattering of round, black pigment dots. The stomach and intestine show bright pink from ingested food.

This specimen differs in general appearance from that of the 35.5 mm male in the somewhat slimmer body, shorter head and larger eye, which interrupts the cephalic profile. But in the arrangement of the teeth and the relative positions of the pelvic, dorsal and anal fin the two specimens are very similar. The rays of the paired fins are not divided into two groups. The pectoral is broken, but the longest pelvic rays almost reach the base of the caudal fin.

Digestive System: The digestive system corresponds to that of the young male in every particular. There are four short caeca, .8 mm in length.

Reproductive System: The ovaries are duplicates in miniature of those found in the mature female subsequently described. They are filled with exceedingly minute, unripe eggs.

MATURE FEMALE: *Trawling Data:* Department of Tropical Research No. 13,062a; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 418; Sept. 4, 1929; 10 miles south of Nonsuch Island, Bermuda; 700 fathoms; Standard length 85 mm.

Measurements and Counts: Total length 98.5 mm; standard length 85 mm; depth 10 (in length 8.5); head 36 (in length 2.4); eye 4.7 (in head 7.7); snout 17 (in head 2.1); pectoral rays 14, broken off short; pelvic rays 9; pelvic length 19; dorsal rays 11; anal rays 10; caudal rays IX + 10 + 10 + XI.

External Characters: The pigmentation of the head is close to that of *D. binocularis* (Fig. 16); that of the trunk resembles the markings of the young male (Fig. 20B), except that in the present specimen the chromatophores are much more pronounced, and that the rays of the paired fins are pigmented in the following fashion: The uppermost 7 pectoral rays are peppered throughout their length with small chromatophores. All of the pelvic rays are heavily pigmented across their bases; the fourth, fifth and sixth are pigmented throughout their length and are the longest; and the third and seventh rays are pigmented in their distal thirds as well as their bases.

In general proportions this specimen approaches the 35.5 mm male more closely than the 40 mm female. The eyes do not interrupt the dorsal profile. The teeth of the upper jaw are all inside its margin on the roof of the mouth and are in three or four rows. Those in the mandible are uniserial. The pelvic, dorsal and anal fins are inserted in the same relative positions as in the two smaller adults. The longest pelvic rays extend almost to the first caudal spines.

Digestive System: In every detail the digestive system of this large specimen is exactly similar to those of the smaller fish already described.

Reproductive System: The ovaries are slender, ribbon-like organs extending the length of the coelomic cavity. They are broadest anteriorly, measuring .9 mm, but posteriorly they dwindle to a mere thread. No oviduct is visible. The eggs have already been described (p. 72).

Ecology

Vertical and Seasonal Distribution: Due to the small number of specimens taken, no bathymetric and seasonal conclusions can of course be drawn. However, it may noted be that all four occurred in the mid-depth region—between 600 and 800 fathoms—which is so typical of all of the Bermuda Alepocephalids. In Fig. 19 is indicated this Bermuda vertical distribution in relation to the depths at which previously recorded specimens occurred. The present specimens were caught in April and September only.

Sociability: The two smallest specimens came up in the same net. In a species as rare as this, it is almost certain that this was not accidental but that the fish were actually swimming together.

ABUNDANCE: This is one of the rarest of deep-sea fish. Even within the narrow limits of its Bermuda vertical distribution (600 to 800 fathoms), it occurred in less than .8 per cent of the nets drawn between those depths.

FOOD: The stomachs of the two smaller fish were partially filled with finely digested, unrecognizable material; that of the 85 mm female was quite empty. In all of the specimens there were small quantities of food in the intestines.

STUDY MATERIAL

The following list gives the catalogue number, net, depth in fathoms, date, length and growth stage of the Bermuda specimens of *Dolichopteryx longipes*. All were caught in the cylinder of water off the Bermuda coast described on p. 5.

No. 8,827; Net 22; 600 F.; April 15, 1929; 35.5 mm; Adult.
No. 8,827a; Net 22; 600 F.; April 15, 1929; 23 mm; Adolescent.
No. 13,062a; Net 418; 700 F.; Sept. 4, 1929; 85 mm; Adult.
No. 18,400; Net 862; 800 F.; Sept. 8, 1930; 40 mm; Adult.

No. 8,827 (KOH No. 1150) was cleared and stained in order to study the skeleton.

The following material is filed: Colored plate B732; outline drawings B894, B895 and B897; photographs B5696 and B5821-L.

SYNONYMY AND REFERENCES

Aulostoma? longipes:

Vaillant 1888, p. 340, pl. XXVII, fig. 4. (1 specimen; 45 mm; 1163 m.; coast of Morocco; *type specimen*).

Goode and Bean 1895, p. 484, fig. 397. (Résumé of type description).

Dolichopteryx longipes:

Norman 1930, p. 271, fig. 3. (2 specimens; 120 and 100 mm; 350–400 (–0) m. and 2500–2700 m.; off Cape Town and Liberia respectively).

Dolichopteryx anascopa:

Brauer 1902, p. 127. (1 specimen; 34.8 mm; 2400 m.; Indian Ocean west of Cocos Island).

Brauer 1906, p. 24, fig. 4. (Supplementary description of *D. anascopa* with discussion of its possible synonymy with *A? longipes*).

Dolichopterygiella:

Roule and Angel 1930, p. 69. The majority of this series of 7 specimens is probably *D. longipes;* 8 to 76 mm; 0–4000 m.; eastern Atlantic, off North Africa.

Macromastax Beebe 1933

GENERIC CHARACTERS: Elongate, moderately compressed Alepocephalids, with naked, delicate skin, no sign of tubercles, and no nuchal dermal fold; lateral line distinct; the head large (less than 3 in length); the mouth very large, with the maxillary reaching far beyond the posterior margin of the orbit; the jaws nearly equal; snout short; the teeth uniserial, absent from the vomer, but present on the premaxillary, maxillary, mandible and palatine; the eye large; the gill membranes not joined beneath the isthmus; 9 branchiostegals; the paired fins are close to the ventral profile; the pectorals small and feeble; the pelvics well-developed, just within the posterior half of the fish; the dorsal is about twice as long as the anal, originating far in advance of it, at the vertical of the pelvics; caudal well-developed, forked.

COMPARISON WITH OTHER GENERA: This genus is immediately distinguishable from other scaleless Alepocephalids by means of the following characters:

From *Xenodermichthys* and *Rouleina* by the inequality of the vertical fins, the forward position of the dorsal, and the great size of the maxillary.

From *Leptoderma* by the shortness of the vertical fins, the fact that the dorsal is longer than the anal instead of vice versa, and by the great size of the maxillary.

From *Anomalopterus* and *Photostylus* (see p. 82) by the absence of an adipose fold in front of the dorsal fin.

In addition to its lack of scales, *Macromastax* differs most obviously from the remaining Alepocephalids as follows:

From *Bathytroctes* (including *Talismania*) in the great length of the maxillary, in the presence of 9 instead of 7 branchiostegals, and in the absence of vomerine teeth.

From *Bajacalifornia* in the lack of a pointed, symphysial knob, and in the large size of the maxillary.

From *Narcetes* in having uniserial instead of polyserial teeth, and more than 7 branchiostegals.

From *Alepocephalus* (including *Conocara*), *Asquamiceps*, *Ericara*, *Leptochilichthys* and *Xenognathus* in the presence of maxillary teeth.

From *Platytroctes* in the presence of pelvic fins.

From *Aulostomatomorpha* and *Dolichopteryx* in the shortness of the snout and great size of the jaws.

Macromastax gymnos Beebe 1933

(Fig. 22)

TYPE: Department of Tropical Research No. 10,829; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 210; June 22, 1929; 8 miles south of Nonsuch Island, Bermuda; 1000 fathoms; Standard length 35 mm.

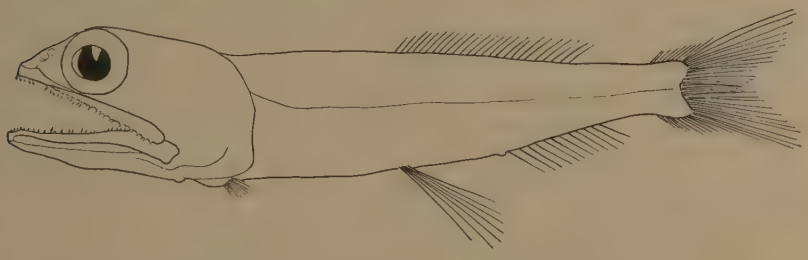


Fig. 22. *Macromastax gymnos* Beebe. × 2.6.

MEASUREMENTS AND COUNTS: (These measurements were made from the fresh specimen). Total length 42.2 mm; standard length 35 mm; depth 6.5 (in length 5.4); head 12.8 (in length 2.7); eye 3.5 (in head 3.7); snout 2.1 (in head 6.1); maxillary 8.5 (in head 1.5); pectoral ca. 10; pectoral length 2.2; pelvic 7; pelvic length 6.3 dorsal 25; anal 12; 9 branchiostegals.

GENERAL DESCRIPTION: Moderately elongate and compressed, the head very large, deeper than the body and contained 2.7 in the length. In the fresh specimen, body pale grayish, peduncle and caudal fin lighter, the latter with many irregular, white marks; head, opercles and body cavity jet black; iris blue-black. Top of head straight, dipping abruptly at front of eye to short, blunt snout; dorsal and ventral profiles almost horizontal, the slope being very slight to the short, thick peduncle; eye very large, 3.7 in head, almost filling the space between the top of the head and the maxillary line; pupil elliptical; nostrils large, oval, half-way between eye and snout,

with a conspicuous, raised rim, showing white, narial tissue, and an elevated, anterior flap; the mouth is exceedingly long, the maxillary 1.5 in head, and straight.

There are 5 short, recurved teeth on each premaxillary ramus, and 24 along the maxillary, separated and rather irregular; on the posterior third these tend to be arranged in pairs; on the mandible are 44 teeth, equally small and curved; some of these are not in perfect alignment, but there is no evidence of biseriality; each palatine has 6 teeth, but there are none on the vomer.

The skin is thin and scaleless, the lateral line well marked, horizontal except near the opercle where it rises gently. The gill opening is large; the gill membranes quite free from the isthmus; there are 9 branchiostegals.

The dorsal fin is low and is twice as long as the equally low anal; the former begins far in advance of the anal, over the origin of the pelvics; the pectorals are close to the ventral profile and beneath the opercular membranes, very short and quite functionless, although the 10 minute rays are fully webbed; the pelvics are well-developed, elongate, close behind the center of the body, and also close to the ventral line; the last rays of each are inserted so close together that they almost touch.

Type in the collections of the Department of Tropical Research of the New York Zoological Society.

REFERENCE

Macromastax gymnos
Beebe 1933, p. 162, fig. 40. (Type description).

Photostylus Beebe 1933

This genus differs from all the *Alepocephalidae* except *Anomalopterus* in having a prominent pre-dorsal fold or adipose fin along the back. It differs from that and other closely related genera (such as *Rouleina* and *Xenodermichthys*) in its steeply ascending, concave snout, small head and relatively high and well developed pectoral fins. The skin is without scales; the jaws are equal, with a prominent symphysial knob; the mouth moderately large; teeth present on the premaxillary, maxillary, mandible and palatine; 6 branchiostegals; pectorals large and placed high; pelvics small; vertical fins almost equal, far back.

Photostylus pycnopterus Beebe 1933

(Fig. 23)

TYPE: Department of Tropical Research, No. 10,217; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 137; May 30, 1929; 9 miles south-east of Nonsuch Island, Bermuda; 800 fathoms; Standard length 64 mm.

MEASUREMENTS AND COUNTS: (From fresh specimen, now shrunken as to length and eye). Total length 71 mm; standard length 64 mm; depth 9.2 (in length 6.9); head 11 (in length 5.9); eye 2.5 (in head 4.4); interorbital 2.5 (in head 4.4); snout 4 (in head 2.7); maxillary 5.8 (in head 1.9); branchiostegals 6; pectoral rays

Fig. 23. *Photostylus pycnopterus* Beebe. × 1.5.

18; longest pectoral ray 4.3; pelvic rays 6; pelvic length 4; dorsal 13½; anal 17½; caudal rays ca. 35; caudal tip slightly broken.

GENERAL DESCRIPTION: Considerably elongate and compressed; body profiles almost horizontal, sloping very slightly backward to the tail; the nape is somewhat elevated, and the head depressed, the top of the head curving evenly down to the eye, from whence to the tip of the snout the profile is concave; the ventral profile of the mandible extends obliquely downward, with a prominent posterior angle, well below the profile of the head; the vertical fins arise from elevated fleshy bases, considerably increasing the depth of the posterior body profile.

The head is small and considerably depressed when compared with other *Alepocephalids;* the snout is blunt; eye small, placed centrally in the head, pupil small; nostrils very large, roughly triangular, separated by a narrow septum, much closer to eye than to tip of snout; mouth moderately large, jaws equal in front; the symphysis of the mandible is prolonged downward (not forward as in *Bajacalifornia*) into a prominent knob; the maxillary is flat and greatly widened posteriorly, extending to the vertical of the posterior border of the eye.

Small teeth in uniserial rows are present on the premaxillary (27), maxillary (17), mandible (24), and palatine (2); the vomer is toothless; the teeth are close-set but besides the symphysial gaps, there are other occasional, narrow, asymmetrical gaps and a few replacement teeth.

The skin is smooth, not noticeably thin, and scaleless even along the lateral line; the gill membranes are free from the isthmus. The head and body are covered with an irregular scattering of photophores, elevated on stalks: These consist of a terminal pigmented body, with a white or iridescent summit, the whole elevated on a thick, colorless stalk. These are most abundant on the sides of the head, along the jaws, on opercles and branchiostegals. On the body they are irregular and asymmetrically distributed, no portion, even the fin-rays, being quite free from them.

From the inter-mandibular membrane arise four pairs of singular looking organs, leaf-like but rather thick and dead white. Together with several small, adjacent patches, these seem to form an illuminating organ, comparable with nothing with which I am familiar in any other Alepocephalid.

The vertical fins are short, rather high, and placed far back on the body; the anal is slightly the longer, originating a little in advance of the dorsal; the caudal is well-developed, slightly forked; there are a few photophores scattered over the bases of all vertical fins; the pectorals are many-rayed, only slightly below the lateral line, and well above the ventral profile; pelvics shorter, very low, and about the middle of the body. On the nape, just back of the vertical of the fleshy base of the pectorals, there rises a thick, fleshy, median fold or adipose fin. This increases slightly in height and extends back to the dorsal, where it merges with the raised, fleshy base of that fin.

Looked at as a whole, this fish bears an amazing superficial resemblance to a larval Melanostomid—in particular in the low-swung head, the prominent mandibular angle and the fleshy bases of both paired and vertical fins.

Type in the collections of the Department of Tropical Research of the New York Zoological Society.

Reference

Photostylus pycnopterus
Beebe 1933, p. 163, fig. 41. (Type description).

Genus **Xenodermichthys** Günther 1878

GENERIC CHARACTERS: Form moderately elongate, much compressed; body naked or with minute, rudimentary scales; tubercular luminous organs present at least on trunk; head moderately large; minute teeth at least on premaxillaries and mandible; 6 or 7 branchiostegals; paired fins small; dorsal and anal equal, fairly long (27 to 33 rays each) and about opposite.

NUMBER OF SPECIES: The genus *Xenodermichthys*, as now distinguished from *Rouleina*, includes three species, one of which was taken by the Bermuda Oceanographic Expeditions. All three are closely related, and the two Atlantic species are probably synonymous.

GEOGRAPHICAL DISTRIBUTION: *X. copei* (Gill 1884), previously known only from the type specimen, is from the western Atlantic; *X. socialis* Vaillant 1888 has been taken at many stations in the eastern and south-eastern Atlantic; *X. nodulosus* Günther 1878, also known only from the type, was taken by the *Challenger* off Japan. (See fig. 24).

VERTICAL DISTRIBUTION: *Xenodermichthys* has been taken at depths ranging all the way from 82 to 2949 fathoms (150 to 5393 meters); the Bermuda examples were caught at 600 and 700 fathoms (1097 and 1280 meters).

ABUNDANCE:

World: As has already been said, two of the three species in the genus have previously been known only from the type specimens. *X. socialis* has been taken about 20 times.

Bermuda: This fish is very rare in the Bermuda hauls.

SOCIABILITY: Although all three of the Bermuda specimens were taken singly, 133 of the young fish recorded by Vaillant (1888 p. 165) came up in the same net, while 3 of the Monaco Expeditions examples were taken at the same time (Roule and Angel, 1930, p. 12). Hence schooling does indubitably occur within the genus.

FOOD: A young Bermuda specimen had fed upon small crustaceans.

ENEMIES: *Xenodermichthys* has not yet been found in the stomach of any animal, nor have parasites been observed.

VIABILITY: There is no record of a living *Xenodermichthys* having been brought to the surface.

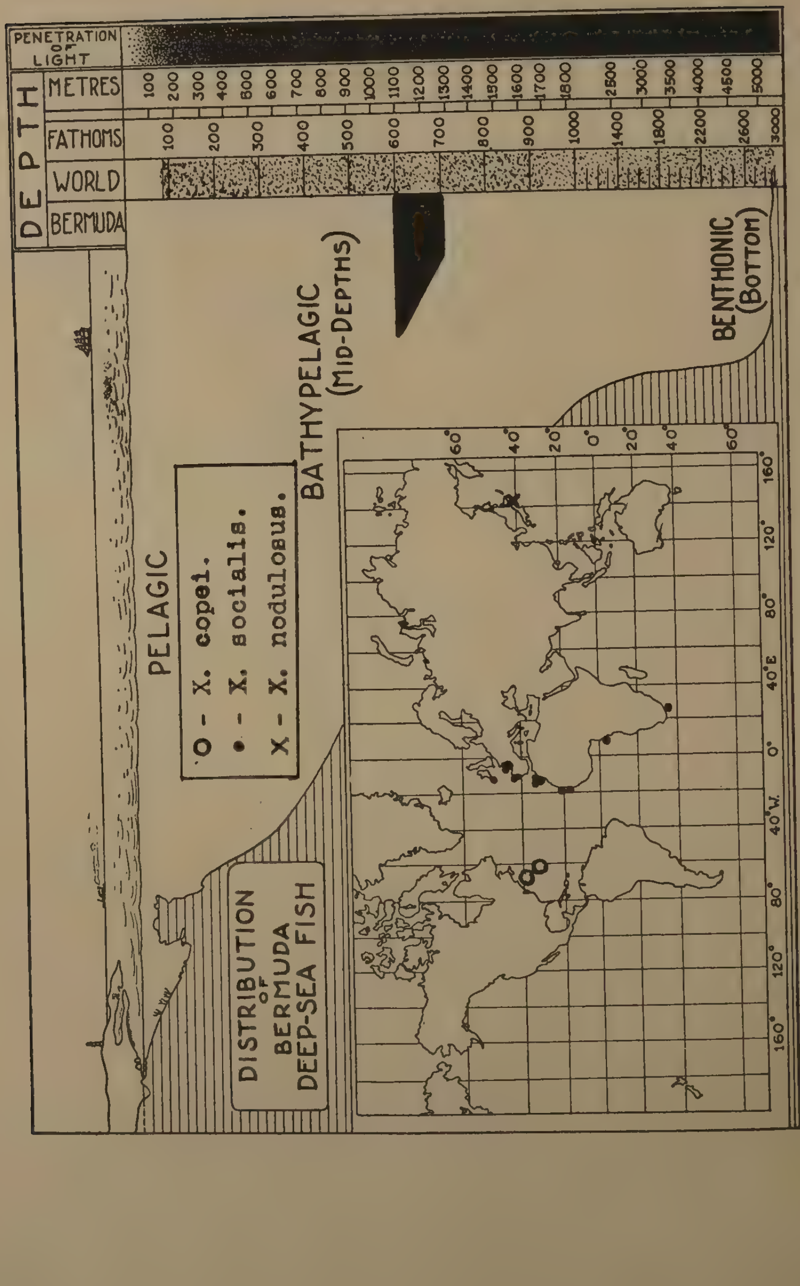


Fig. 24. *Xenodermichthys* Günther. The approximate geographical and vertical distribution of all recorded specimens of the genus. The relative number of specimens taken by the Bermuda Oceanographic Expeditions at 600 and 700 fathoms (the limits of its Bermuda vertical range) is shown diagrammatically at the right, for comparison with the previously known vertical range of the genus.

SIZE: The largest specimen of the genus on record is Günther's *X. nodulosus*, which measured about 200 mm in length. The smallest is the 20 mm specimen of *X. socialis*, recorded by Holt and Byrne (1908, V, p. 48), from off the south-west coast of Ireland.

The three examples of the present collection are all adolescent, measuring between 27 and 34 mm.

Xenodermichthys copei (Gill 1884)

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

3 specimens; September only; 1929 and 1930; 600 and 700 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; Standard lengths from 27 to 34 mm.

PREVIOUSLY RECORDED SPECIMEN

Type specimen only; 2949 fathoms; Western Atlantic; Standard length 88 mm (Fig. 24).

ADULT SPECIFIC CHARACTERS

As all of the Bermuda specimens are immature, the characteristics of the type alone are given in this place. *Color:* uniform blackish. *Proportions:* Depth in length, 5.5; head in length 3.7; eye in head 2; snout in head 5; maxillary extends to vertical from middle of orbit. *Finray Counts:* Not on record; from figure of the type, dorsal and anal, each, about 28. *Teeth:* Minute, on premaxillary and mandible. *Tubercles:* None visible on head, but numerous on the body (about 101 are shown in the figure of the type). The upper portion of the eye does not interrupt the dorsal profile of the head.

DEVELOPMENT

The three Bermuda specimens are all typical adolescents, characterized by a close resemblance to the adult except in the slenderness of the body and the large head, with somewhat small eye, and in the partially developed skeletal and reproductive systems. A description of one of the smaller specimens (Fig. 25), in which the tubercles were especially well preserved, follows:

Trawling Data: Department of Tropical Research No. 17,509;

Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 822; Sept. 1, 1930; 8 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 27 mm.

Measurements and Counts: Total length 32 mm; standard length 27 mm; depth 5.4 (in length 5); head 8 (in length 3.4); eye 3 (in head 2.7); snout 1.6 (in head 5); maxillary 3.5 (in head 2.3); paired fins too damaged for counting; dorsal rays 27; anal rays 27; 6 or 7 branchiostegals.

External Characters: General color dark brown, darkest on lower part of head, opercles and abdomen, lightest on crown, shoulders and base of caudal. In a fresh specimen of equal size the photophores were dull blue much obscured by pigment.

The considerably compressed, moderately elongate body tapers regularly from shoulders to caudal base, being about two and one-half times deeper at the shoulder than at the narrowest part of the caudal peduncle. None of the fin bases are elevated and all of the rays are short. The head is of moderate size, the forehead sloping very gradually to the short, slightly convex snout. The large, elliptical eye does not interrupt the cephalic profile, and is surrounded by a thick, fleshy fold. The single pair of nostrils is located high on the snout, close to the eye. The mouth is rather small, the broad maxillary extending only to the vertical from about the middle of the eye. Teeth are present in the premaxillary (about 20) and mandible (at least 35 in each half); all are minute, nearly equal, although those in the premaxillary are slightly broader and wider set. The paired fins are both very short, the pelvics reaching to about half way between their origin and that of the anal. The latter is opposite the dorsal and equal to it. The caudal is forked.

There is no trace of scales even in the lateral line. The longitudinal wrinkles set with tiny papillae (remarked in *X. socialis* by Collett, Holt and Byrne, and Roule) are present here also, but are exceedingly minute, being barely visible under low power magnification. They are in the best condition along the middle of the side, just below the lateral line. The latter is complete from opercle to caudal base; it begins just above the dorsal end of the gill opening, descending gradually to the middle of the side, which it reaches at the vertical from the pelvic fin base. From here it continues straight backwards to the caudal base.

The short tubercles surmounted by photophores (in preserva-

tive whitish, clouded by pigment) are distributed as follows over each side of the head and body: Head about 25, small on the crown, larger below the eye (in a border of 4), on mandible, opercles and branchiostegal membranes; body, above lateral line, about 20; body, below lateral line, about 98; total 138. The skin above the lateral line is badly damaged, many of the photophores having evidently been lost, and no evidence of arrangement remains. Below the lateral line, however, from the pectoral base to that of the caudal fin the photophores are arranged, quincunxially, in definite, oblique rows which slant downwards and back. The 98 photophores are distributed among these rows as follows: Between base of pectoral and base of pelvic, 6 rows averaging 6 tubercles each; between base

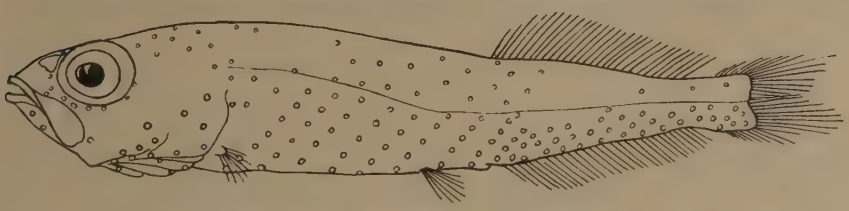


Fig. 25. *Xenodermichthys copei* (Gill). Adolescent specimen, 27 mm. in length.

of pelvic and origin of anal, 2 rows of 5 and 6 tubercles respectively; between origin of anal and base of caudal, traces of at least 15 rows averaging 3 to 4 tubercles each. On the caudal fin are found 4 single lights on the lower fin rays.

Osteology: In the cleared and stained specimen it is seen that the hyomandibular, preopercle, opercle, post-temporal and supracleithrum are fairly well ossified. The parasphenoid, gill-rakers, atlas and first six vertebrae show a lesser degree, while only faint traces are found on the margins of the mandible, quadrate and branchiostegals. The 7th through the 21st vertebrae also show a very light stain, confined in the last of these to the dorsal and ventral profiles alone of the bones. The finrays were all destroyed during the clearing process, but neither the pelvic girdles, the baseosts of the verticals, the hypurals, epurals nor urostyle show the least trace of ossification.

The bones of the right side of the skull are considerably less highly ossified than those of the left.

In so far as it can be determined from the incomplete state of

development of the bones, the structure of the skull is similar to that found in *Alepocephalus productus* (Gregory, 1933; fig. 51).

Digestive System: The relative positions, proportions and shape of the stomach, caeca and intestine are exactly as described and figured by Vaillant (1888, p. 164 and pl. XIII fig. 1g) for *X. socialis*. The black stomach of the present specimen measures 3 mm from the end of the oesophagus, or 1.6 mm from the anterior end of the intestine, to the tip of the blind sac. The six caeca are white. The intestine proceeds straight backwards for some distance, then describes three convolutions in the region of the pelvic fin, followed by an abrupt swelling, which contracts into an elongate, funnel-like neck just before reaching the anus. The last, narrow section is almost black, the remainder of the intestine brown. The position and form of liver and gall-bladder are unknown, as they were torn away through the damaged right side. Lining of coelom, dark brown.

Reproductive System: The gonads extend the full length of the dorsal wall of the coelom as very slender, white strands. They show no evidence of being at all close to breeding condition, and it is impossible to determine the sex of the specimen.

Ecology

Vertical and Seasonal Distribution: The three specimens all were taken at 600 and 700 fathoms in the month of September only.

Food: The single stomach examined was completely filled by a finely digested shrimp. In the anterior two-thirds of the intestine a large amount of unrecognizable crustacean remains was found.

Discussion

The two Atlantic species of *Xenodermichthys, copei* (Gill 1884) from the western Atlantic and *socialis* Vaillant 1888 from the eastern Atlantic, are distinguished in the adult chiefly by the larger head (3.7 in length, not 4 to 4.3) and larger eye (2 in head, not 2.5 to 2.8) of *X. copei*. Due to the immaturity of the present specimens no attempt is made here to decide the question of the identity of the two species. The Bermuda specimens agree slightly better with the descriptions of the young of *X. socialis* by Holt and Byrne (1908, V, p. 48) than with that of the fairly large type speci-

men of *X. copei*. However, the characters involved, such as the small size of the eye, vary from the type only to a degree usually found in young Alepocephalids when compared with older ones, and in view of their geographical occurrence the Bermuda specimens are referred to *copei*.

Study Material

The following list gives the catalogue number, net number, depth in fathoms, date, length and growth stage of each specimen of *Xenodermichthys copei* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast previously described (p. 5).

No. 13,871; Net 511; 700 F.; Sept. 27, 1929; 34 mm; Adolescent.
No. 17,509; Net 822; 600 F.; Sept. 1, 1930; 27 mm; Adolescent.
No. 18,607; Net 890; 600 F.; Sept. 15, 1930; 27 mm; Adolescent.

Specimen No. 17,509 (KOH No. 1147) was cleared and dyed in order to study the skeleton.

In the files is outline drawing no. B509.

Synonymy and References

Aleposomus copei

Gill 1884, p. 433. (Brief preliminary note on the type specimen).

Goode and Bean 1895, p. 47, fig. 51. (Complete description of type specimen).

Jordan and Everman 1896, p. 459. (Résumé of the description by Goode and Bean).

Brauer 1906, p. 21. (Key to the species of *Aleposomus*).

Roule 1919, p. 10. (Discussion of possible synonymy of *A. copei* and *X. socialis*).

Xenodermichthys copei

Norman 1930, p. 270. (Mention of possible synonymy of *X. copei* and *X. socialis*).

Bibliography of References Used in the Present Paper

Alcock, A.
1889 Natural History Notes from H. M. Marine Survey Steamer "Investigator." Ann. Mag. Nat. Hist., (6) 4.
1890 Natural History Notes from H. M. Indian Marine Survey Steamer "Investigator." Ann. Mag. Nat. Hist., (6) 6.

Barnard, K. H.
1925 A Monograph of the Marine Fishes of South Africa. Pt. I. Ann. South African Mus., Vol. 21.

Beebe, W.
1929 Deep Sea Fish of the Hudson Gorge. Zoologica, Vol XII, No. 1.
1931 Bermuda Oceanographic Expeditions 1929–1930. Introduction. Zoologica, Vol. XIII, No. 1.
1931 Bermuda Oceanographic Expeditions 1929–1930. List of Nets and Data. Zoologica, Vol. XIII, No. 2.
1932 Bermuda Oceanographic Expeditions 1931. Individual Nets and Data. Zoologica, Vol. XIII, No. 3.
1932 Nineteen New Species and Four Post-larval Deep-sea Fish. Zoologica, Vol. XIII, No. 4.
1933 Deep-sea Isospondylous Fish: Two New Genera and Four New Species. Zoologica, Vol. XIII, No. 8.

Brauer, A.
1902 Sitz. Ges. Beford. Ges. Naturwiss. Marburg, 1901, No. 8.
1902 Diagnosen von neuen Tiefseefische, welche von der Valdivia-Expedition gesammelt sind. Zool. Anz. V. 25, No. 668.
1906 Die Tiefsee Fische, I. Systematischer Teil. Wiss. Ergebnisse Deutsch. Tiefsee. Exp. Valdivia, Vol. 15, Lief 1.

Collet, R.
1896 Poissons provenant des campagnes du yacht "L'Hirondelle" (1885–88). Result. Camp. Sci. Monaco, Vol. 10.

Garman, S.
1899 The Fishes. Report on an exploration . . . . by the U. S. Fish Commission Steamer "Albatross," during 1891. Mem. Mus. Comp. Zool., Harvard Coll., Cambridge, Mass.

Gilbert, C. H.
1891 Preliminary report on the fishes collected by the steamer Albatross on the Pacific coast of North America during the year 1889. Proc. U. S. Nat. Mus., Vol. 13, 1890 (1891).

Gill, T. N.
1884 Diagnosis of new genera and species of deep-sea fish-like vertebrates. Proc. U. S. Nat. Mus. Vol. 6.

Goode, G. B., and Beane, T. H.
1895 Oceanic Ichthyology. A treatise on the deep-sea and pelagic fishes of the world. Special Bull. U. S. Nat. Mus.

GREGORY, W. K.
1933 Fish Skulls: A study of the Evolution of Natural Mechanisms. Trans. Amer. Philosoph. Soc., New Series, Vol. XXIII, Part II.
GÜNTHER, A.
1878 Preliminary notes of deep-sea fishes collected during the voyage of H. M. S. "Challenger." Ann. Mag. Nat. Hist. (5) 2.
1887 Report on the deep-sea fishes. Rept. Sci. Res. "Challenger," Vol. 22, 1887.
HOLT, E. W. L., AND BYRNE, L. W.
1908 Second report on the fishes of the Irish Atlantic Slope. Fisheries, Ireland, Sci. Invest. 1906, V. (1908).
JORDAN, D. S., AND EVERMANN, B. W.
1896 The fishes of North and Middle America, Vol. I. Bull. U. S. Nat. Mus., 1896.
KOEHLER, R.
1896 Résultats scientifique de la campagne du "Caudan" dans le Golf de Gascogne. Ann. Univ. Lyon, Paris, Fasc. 26.
MURRAY, SIR J. AND HJORT, J.
1912 The Depths of the Ocean. A General Account of the Modern Science of Oceanography Based Largely on the Scientific Researches of the Norwegian Steamer "Michael Sars" in the North Atlantic.
NORMAN, J. R.
1930 Oceanic Fishes and Flatfishes Collected in 1925–1927. Discovery Reports, Vol. II.
ROULE, L.
1916 Notice preliminaire sur quelques espèces nouvelles ou rares des poissons provenant des croisières de S. A. S. le Prince de Monaco. Bull Inst. Oceanogr. Monaco, No. 320.
1919 Poissons provenant des campagnes du yacht Princesse Alice et du yacht Hirondelle II. Res. Camp. Sci. Monaco, Fasc. 52.
ROULE, L. AND ANGEL, F.
1930 Larves et Alévins de Poissons provenant des Croisières du Prince Albert de Monaco. Res. Camp. Sci. Monaco, Fasc. 79.
1931 Observations et rectifications concernant divers Poissons recueillis par S. A. S. le Prince Albert I de Monaco au cours des campagnes 1911 a 1914. Bull. Inst. Ocean. Monaco, No. 581.
1933 Poissons provenant des campagnes du Prince Albert I de Monaco. Res. Camp. Sci. Monaco, Fasc. 86.
VAILLANT, L.
1888 Poissons, Exp. Scient. "Talisman et Travailleur."
WEBER, M.
1913 Die Fische der Siboga-Expedition. Siboga-Expeditie, Monog. 57, Livr. 65.
ZUGMAYER, E.
1911 Poissons provenant des campagnes du yacht "Princesse Alice" (1901–1910). Res. Camp. Scient. Fasc. 35.

Zoologica, Vol. XVI, No 3

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

Family ARGENTINIDAE*

By William Beebe

(Figs. 26–46 incl.)

* Contribution, New York Zoological Society, Department of Tropical Research, No. 418.

Zoologica, Vol. XVI, No. 3.

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

Family ARGENTINIDAE

By William Beebe

ARGENTINIDAE

Salmonoid Isospondylous fishes having an orbitosphenoid, no opisthotic, no upturned vertebrae at base of caudal fin, no teeth on the meso-pterygoids, a mesocoracoid and inferior parapophyses.

Genus **Bathylagus** Günther 1878

Generic Characters: Body compressed and elongate, covered with thin, deciduous scales of medium size; no regular photophores; head short and compressed, with thin, membranous bones; mouth very small, transverse, anterior; maxillary very short, dilated; the teeth of both premaxillary and maxillary rudimentary or absent; minute teeth present on mandible, vomer and palatine; eye very large; pectoral and pelvic fins inserted close to ventral profile, the pelvics under the dorsal which is close to the middle of the body; anal fin moderate, with up to about 25 rays; adipose fin present; gill opening narrow; gill membranes united and not attached to isthmus; gill-rakers rather long; pseudobranchiae well developed; 3 or 4 branchiostegals.

Number of Species: Twelve species have been recorded, of which two have been taken by the Bermuda Oceanographic Expeditions.

Geographical Distribution: Members of the genus are known from the Atlantic and Antarctic Oceans and from the Pacific coast of North and Central America.

Vertical Distribution: The species of *Bathylagus* are all bathypelagic. Most of the Bermuda examples came from between 600 and 800 fathoms, with an extreme range of 400 to 1000 fathoms. The temperatures in the trawling area at the latter depths were found to be about 52.8° Fah. (11.5° C.) and 38.7° Fah. (3.7° C.)

respectively. The pressures at the same depths are 1176 and 2940 pounds per square inch.

ABUNDANCE:

World: All of the species of *Bathylagus* have been known previously from less than a score of specimens each.

Bermuda: A total of 119 specimens have been taken by the Bermuda Oceanographic Expeditions. In the order of abundance of individuals in the nets, *Bathylagus*, the only deep-sea representative of its family, ranks seventh among the deep-sea *Isospondyls* (in a total of 42 genera) and about fifteenth among all of the deep-sea fishes (including at least 120 genera).

SOCIABILITY: The two Bermuda species of the Bermuda collection show some evidence of sociability, two or three specimens, not always of approximately the same size, having been found in a single net upon thirteen occasions. Only once, however, were specimens of both *B. benedicti* and *B. glacialis* brought up in the same net.

FOOD: Of the seventeen stomachs examined only four contained any food at all; this consisted entirely of small crustaceans. Unrecognizable matter was, however, present in most of the intestines.

ENEMIES: *Bathylagus* has not yet been found in the stomach of any animal, nor have parasites been observed.

VIABILITY: None of the Bermuda specimens has been brought alive to the surface.

SIZE: The longest known specimens measure about 200 mm. The largest Bermuda female, of 94 mm, seemed near breeding condition.

DEVELOPMENT: Adolescents far outnumber the uncommon post-larvae and rare adults in the Bermuda collection. All occurred throughout the Bermuda trawling seasons from April to September. No larvae were taken.

In comparison with the adults, the young of both species have in common the following traits: A slight to moderate amount of pigment; slender bodies; small eyes; mandibular teeth developing more rapidly than those of the vomer and palatine with which they articulate; scales appearing in early adolescence, at 25 or 30 mm; unpaired fins almost fully developed in post-larval stage, ahead of the paired fins; traces of finfolds persisting into late adolescence as elongate adipose fins; jaws, parasphenoid, proximal parts of

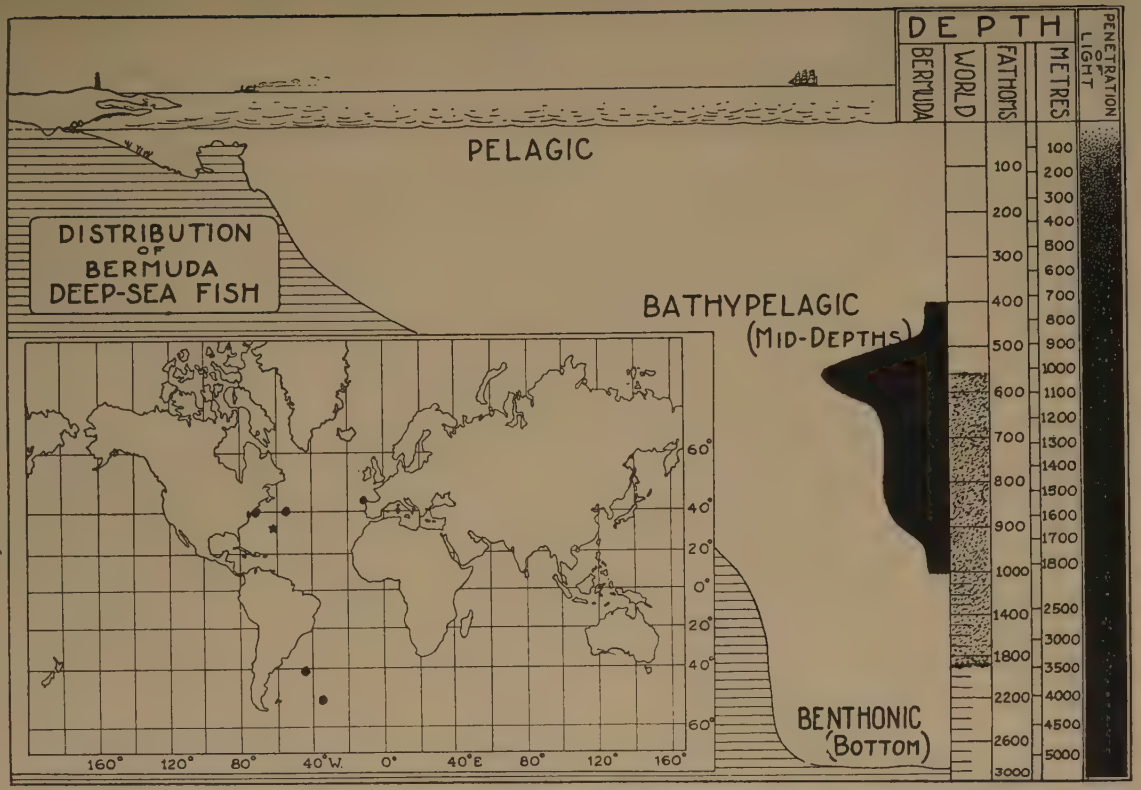


Fig. 26. *Bathylagus benedicti* Goode and Bean. The approximate geographical and vertical distribution of all recorded specimens. The relative number of specimens taken at different depths by the Bermuda Oceanographic Expeditions is shown diagrammatically at the right, for comparison with the previously known vertical range of the species.

finrays, caudal base and anterior vertebrae in the order named are the first bones to ossify.

The general characteristics of the post-larvae, adolescents, and adults of *Bathylagus* agree with the definitions of those stages given in the Introduction (p.); their specific characteristics will be found in succeeding pages in the discussions of the development of each species.

KEY TO THE IMMATURE SPECIMENS OF BERMUDA BATHYLAGUS

A. General body color pale brownish with two conspicuous, lateral bands of pigment spots, one above and one below lateral line, from shoulder to caudal base; eyes, viewed from above, not converging anteriorly ..... *B. glacialis*

AA. General body color blackish; no lateral rows of pigment spots; eyes, viewed from above, definitely converging ..... *B. benedicti*

Bathylagus benedicti Goode and Bean 1895

SPECIMENS TAKEN BY THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

20 specimens; April to September, 1929 to 1931; 400 to 1000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; Standard lengths from 18 to 91 mm.

PREVIOUSLY RECORDED SPECIMENS

9 specimens; 550 to 1925 fathoms; North and South Atlantic; Standard lengths from 108 to 158 mm. (Fig. 26).

ADULT SPECIFIC CHARACTERS

(Fig. 27B)

Bathylagus benedicti is deeper (depth 5 to 5.6 in length) than any of the other members of the genus having the dorsal origin nearer snout than caudal base and the anal with at least 16 rays, except *B. antarcticus, B. pacificus* and *B. euryops.* From the first it is distinguished by the fewer anal rays (19, not 22 to 25), from the second by the smaller head (4.2 to 4.3, in length, not 4 to 4.1) and larger eye (about 2 in head, not 2.25 to 2.5), and from the third by the longer base of the anal fin (about 5.6 in length, not 6.2 to 6.7). *Color:* Skin of whole body as well as deeper layers of dermis dark

brownish or blackish; scale pouches rimmed with black; the darkest regions are the interorbital, lower part of head, opercles and abdomen. *Proportions:* Depth in length 5 to 5.7; head in length 3.9 to 4.3; eye in head 2 to 2.2, greater than post-orbital region; interocular width in head 2.7 to 3.2, interorbital width in head 5.7 to 6.4; snout in head 6; origin of dorsal nearer snout than base of caudal; pelvic origin under last half of dorsal; origin of anal 2.9 to 3.2 times as distant from end of snout as from base of caudal; length of anal base in that of fish 5.6 to 5.7. *Finray Counts:* Pectoral 10; pelvic 9; dorsal 9 to 10; anal 18 to 19. *Teeth:* Rudimentary or absent in premaxillary and maxillary; minute and fairly numerous on mandible, vomer and palatine. *Scales:* About 40 in a longitudinal series. *Gill-rakers:* About 13 in lower part of first branchial arch.

Development

The Bermuda collection contains nineteen young fish and one which is probably completely mature. The young specimens fall into two groups, the first consisting of specimens with characters about intermediate between a post-larval and adolescent stage, and a second group of older fish which are obviously typically adolescent. The relation of these growth stages to standard length and numerical abundance is shown in the following table.

Transition Stage Between Post-Larva and Adolescent: (Fig. 27A). Eight specimens of the post-larval transition stage were taken, measuring between 18 and 22 mm. They differ from adolescents and adults in their proportions, the presence of finfold traces, and the lack of ossification. They are referred to a transition stage rather than to the true post-larval due to the following points: All of the finrays are distinct; there is no characteristic contour unlike adolescent and adult, as is so frequently found in post-larvae; and the scales are well developed.

Trawling Data: For the description of all of the characters except those of the skeletal system the following specimen was selected: Department of Tropical Research No. 9,653; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 41; April 25, 1929; 12 miles south-east of Nonsuch Island, Bermuda; Standard length 18 mm.

No. 15,416 (Cleared and Stained Collection No. 1064), 18 mm, was examined for skeletal characteristics.

THE RELATION OF GROWTH STAGE TO LENGTH AND NUMERICAL ABUNDANCE IN *Bathylagus benedicti*

Length in mm	Larvae	Transitional Larvae	Post-larvae	Transitional Post-larvae	Adolescents	Transitional Adolescents	Adults	Total
18–20				7				7
21–23				1				1
24–26					2			2
27–29					1			1
30–32					1			1
33–35					2			2
36–38					3			3
39–41					1			1
42–44								
45–47								
48–50								
51–53					1			1
91							1	1
	—	—	—	—	—	—	—	—
				8	11		1	20

Measurements and Counts: Total length 21.7 mm; standard length 18 mm; depth 2.7 (in length 6.7); head 5.4 (in length 3.3); eye 1.9 (in head 2.8); snout .75 (in head 7.2); maxillary 1.3 (in head 4.6); interocular 1.9 (in head 2.8); snout to anal origin 14, the first finray 3 times nearer caudal base than tip of snout; anal base 3 (in length 6); pectoral rays 10; pectoral length 2.7; pelvic rays 9, origin under 7th dorsal ray; pelvic length 1.8; dorsal rays 10; anal rays 18; caudal rays XI + 11 + 10 + X; adipose length 3 (in anal base 1); gill-rakers well developed.

External Characters: The entire fish is brownish, with the body almost uniformly speckled with small black chromatophores. The upper postorbital region is pale and translucent; the interorbital, jaws, opercles and abdomen very dark, brownish-black. Iris black.

The moderately compressed and elongate body tapers symmetrically from the nape to the caudal base, where the depth is over half that of the shoulder. The bases of all of the fins are noticeably elevated.

The top of the head, scarcely raised above the level of the nape, is broad and flattened, the snout convex, and the lips full. The gradual curve of the opercular membranes mark the ventral cephalic profile below the mouth and on backward to the gill opening. The diameter of the eyes is less than the length of the postorbital region

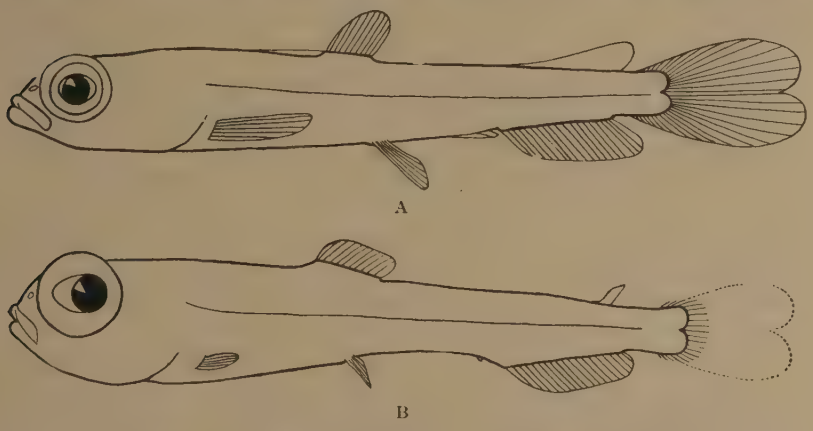


Fig. 27. *Bathylagus benedicti* Goode and Bean. A, transitional post-larva, 18 mm.; B, young adult, 91 mm.

and less than twice that of the snout. They converge anteriorly, their dorsal portion being slightly elevated above the interorbital profile. Although the socket holding the lens has an anterior scallop, which possibly permits a forward movement or rotation of the lens, the iris and eyeball are both perfectly round. The nostrils are widely separated, placed slightly nearer the anterior margin of the eye than the tip of the snout, and are of moderate size. The broad and exceedingly delicate maxillary reaches the anterior edge of the iris.

There are single, close-set series of exceedingly minute teeth on the premaxillary and mandible; maxillary toothless; vomer with one pair of comparatively large fangs; palatine toothless.

Around the eye and along the mandible minute pores are arranged as in the adult. The lateral line follows the midline of the side, and is conspicuous. The operculum extends upwards to the horizontal through the middle of the eye.

The scales are well developed, and, as far as can be determined

from the scale pouches, are arranged as in the adult. Individually, they differ in having only about one-fourth as many circuli as in the adult fish.

The rays of all of the fins are distinct, though very soft. The paired fins are placed close to the ventral profile. The caudal is deeply forked. Between the last of its dorsal profile spines and the first of its long, terminal rays the tip of the urostyle projects obliquely upwards and back. The adipose fin originates in front of the vertical from the anal origin and equals in length the anal base. In front of the dorsal are traces of a finfold, and, ventrally, the extreme tip of the gut protrudes from the remains of a pre-anal finfold.

Skeletal System: There is no trace whatever of ossification.

ADOLESCENT: The adolescents of the collection are eleven in number and measure from 24 to 51 mm. They are typical of that growth stage in closely resembling the adult, but in having minor external differences, a partially ossified skeleton and immature gonads. Descriptions of characteristic examples follow.

Trawling Data: All of the characters except those of the skeletal system are taken from Department of Tropical Research No. 12,418; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 380; Aug. 16, 1929; 8 miles south of Nonsuch Island, Bermuda; 700 fathoms; Standard length 37 mm.

No. 11,414 (Cleared and Stained Collection No. 860), length 40 mm, furnishes the data for the remarks on the skeletal system.

Measurements and Counts: Total length 42.2 mm; standard length 37 mm; depth 6.6 (in length 5.6); head 9.3 (in length 4); eye 3.8 (in head 2.4); snout 1.6 (in head 5.8); interocular 4 (in head 2.3); interorbital 2.4 (in head 3.9); distance from snout to anal origin 29, the first finray 3.1 times nearer caudal base than tip of snout; anal base 6.3 (in length 5.9); pectoral rays 10; pectoral length 2; pelvic rays 9, origin under 8th dorsal ray; length longest pelvic ray 2.3; dorsal rays 10; anal rays 19; adipose length 1.7 (in anal base 3.7); scales in a longitudinal series, about 39; gill-rakers in lower half of 1st branchial arch.

External Characters: The general color, contour and proportions closely resemble those of the adult except that the body is slightly slimmer and the head longer. There are altogether 6 pairs of vomerine and palatine teeth.

The general arrangement of the scales also follows closely that

of the adult in so far as it can be determined from the scale pouches. Two or three lateral line scales remain on each side. Fig. 28B represents one taken from the left side at the vertical from the first anal rays, the 23rd from the opercle. It is an almost circular oval, longer than deep, with the anterior border interrupted by two deep scallops, and the posterior by a key-hole-shaped indentation. Over half of the scale is exposed, and the apical region is decidedly convex, not noticeably thinner or more delicate than the rest of the scale. In general character it is cycloid and marked only by circuli, there being no trace either of annuli, radii or a definite center. There are about 25 circuli between the central canal and the dorsal border, running from the basal portion of the scale straight to the apical margin where they terminate abruptly. An equal number is found ventrally, but from the entrance to the pore duct in the basal portion to the middle of the anterior border there are but eight, spaced over twice as broadly as the more posterior ones just mentioned. The course of the lateral line through the scale is simple and unbranched: One basal pore opens on the outer face of the scale, forming the entrance to a raised duct; this terminates in a central pore opening on the inner face of the scale and in contact with that portion of the succeeding scale which is immediately in advance of its outer, basal pore; finally, there is an apical pore, opening on both outer and inner faces of the scale, its posterior margin confluent through a narrow canal with a central indentation in the posterior margin of the scale; this forms the key-hole-shaped interruption of the border mentioned above; the duct is lined with skin. Length of scale 1.4 mm; breadth 1.3 mm.

Osteology: The jaws and margins of the quadrate are strongly ossified, the parasphenoid and edges of the opercular bones to a lesser degree. The remaining bones of the head show no trace of it. The extreme anterior end of the vertebral column is slightly ossified, while the proximal portions of the pectoral rays, the proximal part of the lower terminal caudal rays, and the end of the interior portion of the urostyle are very feebly ossified. Exteriorly, the unossified tip of the urostyle still projects slightly.

ADULT: (Fig. 27B). But one mature specimen was taken, and it (a male) is not in breeding condition. Its description follows.

Trawling Data: Department of Tropical Research No. 19,529; Bermuda Oceanographic Expeditions of the New York Zoological

Society; Net 962; September 29, 1930; 8 miles south of Nonsuch Island, Bermuda; 800 fathoms; Standard length 91 mm.

Measurements and Counts: Standard length 91 mm; depth 16 (in length 5.7); head 23 (in length 3.9); eye 11.8 (in head 2); snout 3.8 (in head 6); maxillary 4.8 (in head 4.8); interorbital width 3.6 (in head 6.4); interocular width 7.2 (in head 3.2); snout to anal origin 67, the insertion of the first finray 2.9 times nearer the caudal base than the tip of the snout; anal base 16 (in length 5.7); pectoral rays 19; pectoral length (broken) 4.5; pelvic rays 9, originating under 7th dorsal ray; length of longest pelvic ray (broken) 5.2; dorsal rays 10; anal rays 18; adipose length 1.6 (in anal base 10); scales in longitudinal series about 40; gill-rakers in lower half of 1st branchial arch 13.

External Characters: The skin of the whole body is deeply pigmented with brownish black, darkest on the margins of the scale pouches, in the interorbital region, lower part of the head, the opercles and the abdomen, in the order named.

The body is compressed, elongate and deepest in front of the dorsal fin. From here it tapers to the caudal base, which is less than one-third the maximum depth. All of the fin bases are somewhat elevated. The head is rounded in general contour, the crown slightly elevated above the level of the nape, the snout very short and blunt, the full upper lips overhanging the lower, and the united gill membranes, visible ventrally below the tiny mouth, curving backward to the small gill opening. The enormous, round eyes are elevated nearly a fifth of their diameter above the dorsal profile of the interorbital region. They are larger than the postorbital portion of the head and, when viewed from above, converge anteriorly. The socket in which the lens is set is slightly elliptical, with a shallow, anterior scallop, less marked than in the adolescent. The nostrils are widely separated by the broad, flattened, upper surface of the snout, and are placed nearer the anterior margin of the eye than the snout's tip. The delicate, paper thin maxillary extends a little beyond the vertical from the anterior margin of the eye.

The premaxillary and maxillary are entirely toothless. In each half of the mandible 37 very small teeth are found, all equal in size and slanting obliquely backwards, closely resembling the teeth of a saw. These articulate with 9 pairs of slightly larger teeth divided between the vomer and palatine, all triangular and erect, and largest near the premaxillary symphysis.

The gill openings are very small, the dorsal border not reaching the horizontal from the ventral border of the eye.

A number of pores are found around the eye and along the mandible.

All of the scales except one (Fig. 28A) are missing, but judging from the scars, those in the anterior part of the body and on the opercula were fully three times the size of those at the caudal base.

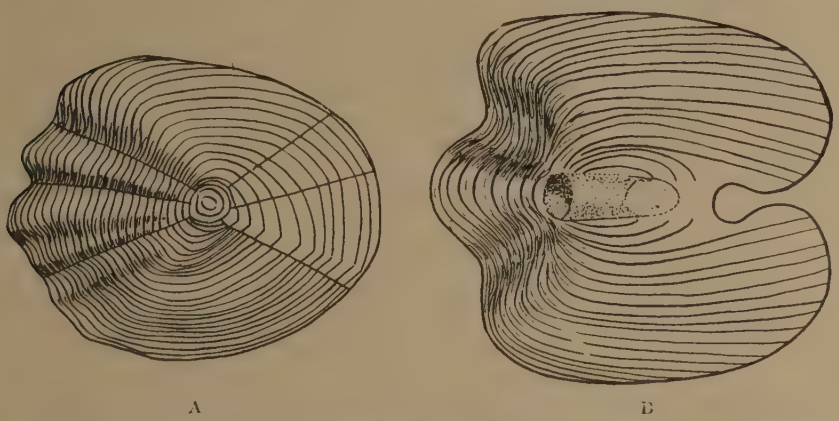


Fig. 28. *Bathylagus benedicti* Goode and Bean. Scales. A, from 91 mm. specimen, 21st scale in 2nd row below lateral line, above anal origin (× 12.5); B, from 37 mm. specimen, 23rd scale in lateral line, above anal origin (× 39).

There were about 40 in a longitudinal series and five rows, exclusive of profile and fin-base rows.

Scaled Areas: The fish is entirely scaled posterior to the vertical from the posterior border of the lens of the eye.

Attachments: The scales are imbricated; each one is very loosely attached within a comparatively shallow, black-lipped pouch, leaving about one-half of the scale exposed. Only one scale was left on this specimen.

Number: The number of scales on the head is indeterminate. On the left side there are about 212. Taking into account the 47 scales of the dorsal and ventral profiles, a total of 518 on the entire body may be regarded as a close approximation of the true number. As the scales themselves are missing, the count has to be made from the scale pouches.

Arrangement: Excluding the scale rows of the dorsal and ventral

profiles, and those of the dorsal and anal fin bases, there are five longitudinal rows of scales, continuous from nape to caudal base. The numbers of scales in these rows, as seen from the left side is as follows:

Dorsal profile—Nape to dorsal origin	7
Dorsal profile—End of dorsal to adipose	16
Dorsal profile—Adipose to caudal base	3
1st row—Along base of dorsal fin	5
2nd row—Nape to caudal base	39
3rd row—Nape to caudal base	39
4th row—Nape to caudal base (lateral line)	40
5th row—Opercle to caudal base	40
6th row—Opercle to caudal base	37
7th row—Along base of anal fin	12
Ventral profile—Isthmus to pelvic origin	9
Ventral profile—Pelvic to anal origin	10
Ventral profile—Anal origin to caudal base	2
Total Number of Scales on Body:	
Paired—(212 x 2)	424
Unpaired—(47 x 2)	94
Total	518

Description of individual scale: The scale illustrated (fig. 28A) is the 21st scale in the second row below the lateral line (the sixth row below the dorsal profile) from the left side of the body immediately above the origin of the anal fin. It is oval, fairly symmetrical, with 5 unequal scallops in the anterior margin. The posterior margin is very thin and fragile. The center is simple, in about the middle of the scale, with the circuli starting at once. There are 35 of them dorsally and ventrally, almost as many anteriorly, but only about a dozen posteriorly. The dorsal and ventral halves of these apical circuli meet at sharp angles in the ventral half of the apical region. Three radii anteriorly connect the deepest scallops with the central region, and three others extend from near the center to the posterior border. There is no trace of annuli. Length of scale 4 mm; breadth of scale 3.2 mm.

The paired fins are broken off short, as are those of the caudal, but the rays are stout and strong, as if they were well ossified, and all double. This applies to a lesser degree in the dorsal and anal, which also appear to be broken. The dorsal, of course, origin-

ates in the anterior half of the fish. The small adipose is placed above the posterior rays of the anal fin.

Reproductive System: The specimen seems unquestionably to be a male. The gonads, which are not in breeding condition, are slender and extend the length of the trunk against the dorsal wall of the coelomic cavity.

SUMMARY OF DEVELOPMENT: The characteristics of the several growth stages, based upon an examination of all of the specimens in the collection, are as follows:

Transition between Post-larval and Adolescent Stages: 8 specimens, from 18 to 22 mm. Body slender (6.7 to 8 in length, not 5.3 to 6.3 as in adolescent and adult); head large (2.7 to 3.25 in length, not 3.3 to 4.5, as in adolescent and adult); eye shorter than or barely equal to post-orbital region; vomerine teeth 1 to 2 pairs; palatine teeth lacking; top of head transparent; upper margin of gill slit opposite middle of eye; scales well developed but with only one-fourth as many circuli as in adult; urostyle tip prominent externally; adipose fin long, contained 1 to 2 times in anal base; traces of predorsal and preanal finfolds; extreme tip of gut projecting; no ossification.

Adolescent: 11 specimens, from 24 to 51 mm. Body approaching adult form (depth 5.3 to 6.3 in length); head approaching adult size (length 3.3 to 4.5 in length of fish); eye as in adult, longer than post-orbital region; vomer and palatine teeth together, 5 or 6 pairs, in continuous series; top of head translucent; upper margin of gill slit opposite middle of eye; scales with two-thirds or more as many circuli as in adult specimen; urostyle tip barely visible externally; adipose fin moderate, contained 3 to 6 times in anal base; no traces of predorsal or preanal finfold; no protruding gut; skeleton partially ossified; gonads undeveloped.

Adult: 1 specimen, 91 mm. Depth 5.7 in length; head 3.9 in length; vomer and palatine teeth together, 9 pairs, in a continuous series; top of head opaque; upper margin of gill slit opposite lower margin of eye; urostyle tip invisible; adipose fin short, contained about 10 times in anal base; (skeleton presumably entirely ossified); gonads well developed.

Ecology

Vertical and Seasonal Distribution: Fig. 29 shows the vertical, monthly and yearly distribution of the specimens of

Fathoms	April			May			June			July			Aug.			Sept.			Total		
	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931
400	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			1			1
																		1			1
500	1				1				1	2			—	—	—		1		3	2	1
		1			1			1			2						1			6	
600	1			—	—	—	—	—	—			1	—	—	—		1		1	1	1
		1									1						1			3	
700	—	—	—		1		—	—	—	1			1			—	—	—		2	1
					1						1			1						3	
800	1			—	—	—	—	—	—	—	—	—	—	—	—	1	1			2	1
		1															2			3	
900	—	—	—	3			—	—	—	—	—	—	—	—	—	—	—	—	3		
					3															3	
1000	—	—	—	—	—	—	—	—	—	1			—	—	—	—	—	—	1		
											1									1	
Total	3			3	2				1	4		1	1			1	3	1	12	5	3
		3			5			1			5			1			5			20	

Fig. 29. *Bathylagus benedicti* Goode and Bean. The vertical, monthly and yearly distribution of the specimens taken by the Bermuda Oceanographic Expeditions.

Bathylagus benedicti taken off Bermuda. The vertical range lay between 400 and 1000 fathoms, with a mean depth of 660 fathoms. The species, which was found during every month of the trawling season (April to September), was most abundant during the alter-

nate months of May, July and September. (See Figs. 30 and 31). Never before has the species been taken as high as 400 fathoms in a horizontal trawl. (See general distribution chart, Fig. 26).

The table below correlates the data of the graphs just mentioned with length and growth stage (discussed under DEVELOPMENT), and gives in addition average depths and lengths:

RELATION OF MONTH, NUMBER OF SPECIMENS, DEPTH, LENGTH AND GROWTH STAGE

		Depth in Fath.:		Length in mm:		
Month	Number	Extremes	Average	Extremes	Averages	Growth Stages
April	3	500–800;	633	18 to 22;	19.3	Transition
May	5	500–900;	780	18 to 25;	21	Transition, Adolescent
June	1	500	500	27	27	Adolescent
July	5	500–1000;	660	31 to 51;	38.2	Adolescent
August	1	700	700	37	37	Adolescent
Sept.	5	400–800;	620	18 to 91;	40.6	Transition, Adolescent, Adult
Total	20	400–1000;	660	18 to 91;	30.7	Transition, Adolescent, Adult

Although there is no evident relation between depth and season, the correlation of season and length is most pronounced: All of the youngest specimens (Post-larval transition stage) except one were taken in the spring, while the larger adolescents and the single adult were confined entirely to the summer and fall (Fig. 32).

SOCIABILITY: *Bathylagus benedicti* shows little evidence of schooling, having been taken singly except in two nets. In each of these two specimens were found, consisting of a transition stage and an adolescent, and of two adolescents, respectively.

ABUNDANCE: Both in comparison with *Bathylagus glacialis* and with other deep sea fish *Bathylagus benedicti* is rare. It is represented in 1.8 percent of all of the nets drawn between 400 and 1000 fathoms, the limits of its vertical distribution.

FOOD: The stomach contents of the seven specimens examined consisted entirely of small crustaceans, distributed as follows:

Length of Specimen	*Contents of Stomach*	*Depth*
18 mm	None	400 Fath.
20 mm	None	600 Fath.
31 mm	None	500 Fath.

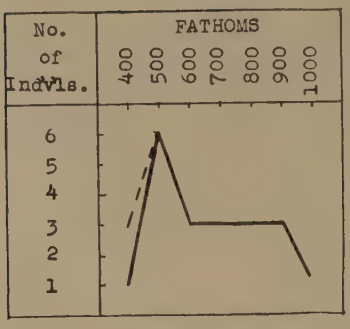


Fig. 30. *Bathylagus benedicti* Goode and Bean. The vertical distribution of the specimens taken by the Bermuda Oceanographic Expeditions. The broken line is based on the number of specimens which would theoretically have been taken at 400 fathoms if as many nets had been drawn at that depth as at the others.[1]

[1] See Introduction, p. 8.

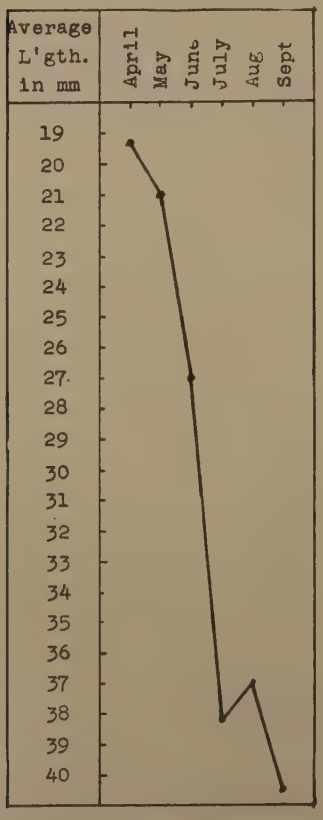


Fig. 32. (*Left*). *Bathylagus benedicti* Goode and Bean. The relation of seasonal distribution to average length, based upon the total number of specimens taken by the Bermuda Oceanographic Expeditions.

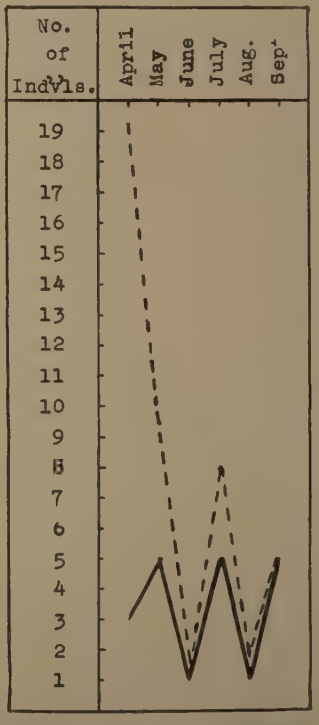


Fig. 31. (*Above*). *Bathylagus benedicti* Goode and Bean. The seasonal distribution of the specimens taken by the Bermuda Oceanographic Expeditions. The solid line is based upon the actual number of specimens taken, the broken line upon the number which would theoretically have been caught if as many nets had been drawn every month as during September.[1]

[1] See Introduction, p. 7.

Length of Specimen	*Contents of Stomach*	*Depth*
35 mm	1 Copepod (length 4.3 mm)	500 Fath.
37 mm	None	700 Fath.
40 mm	7 Copepods (up to 6 mm)	1000 Fath.
	2 young Schizopods	
	1 young Squilla	
	1 young Malacostracan (?)	
91 mm	3 or more minute Copepods	800 Fath.
	1 Isopod	

Unrecognizable material was present in the intestines of all of the specimens.

Study Material

The following list gives the catalogue number, depth in fathoms, date, length and growth stage of each specimen of *Bathylagus benedicti* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described on p. 5. "Transition" indicates specimens intermediate between post-larvae and adolescents.

No. 9,590; Net 33; 600 F.; April 24, 1929; 22 mm; Transition.
No. 9,653; Net 41; 800 F.; April 25, 1929; 18 mm; Transition.
No. 9,721; Net 45; 500 F.; April 29, 1929; 18 mm; Transition.
No. 10,114; Net 116; 900 F.; May 18, 1929; 24 mm; Adolescent.
No. 10,105; Net 117; 900 F.; May 18, 1929; 18, 25 mm; Transition and Adolescent.
No. 11,414; Net 277; 1000 F.; July 9, 1929; 40 mm; Adolescent.
No. 11,512; Net 285; 500 F.; July 11, 1929; 31, 35 mm; Adolescent.
No. 11,796; Net 322; 700 F.; July 24, 1929; 34 mm; Adolescent.
No. 12,418; Net 380; 700 F.; Aug. 16, 1929; 37 mm; Adolescent.
No. 13,071; Net 419; 800 F.; Sept. 4, 1929; 37 mm; Adolescent.
No. 15,416; Net 625; 500 F.; May 23, 1930; 18 mm; Transition.
No. 15,518a; Net 647; 700 F.; May 29, 1930; 20 mm; Transition.
No. 19,116a; Net 923; 600 F.; Sept. 20, 1930; 20 mm; Transition.
No. 19,364; Net 945; 500 F.; Sept. 25, 1930; 37 mm; Adolescent.
No. 19,529; Net 962; 800 F.; Sept. 29, 1930; 91 mm; Adult.
No. 20,810; Net 1015; 500 F.; June 15, 1931; 27 mm; Adolescent.
No. 21,470; Net 1095; 600 F.; July 24, 1931; 51 mm; Adolescent.
No. 23,627; Net 1324; 400 F.; Sept. 18, 1931; 18 mm; Transition.

Nos. 11,414 (KOH No. 860) and 15,416 (KOH No. 1064) have been cleared and stained in order to study the skeleton.

The following paintings and drawings are filed: Colored plate B752; outline drawings B876, B877, and B878.

Synonymy and References

Bathylagus benedicti:

Goode and Bean 1895, p. 55, fig. 64 (3 specimens; 112.5 to 144 mm; 1022 to 1769 fath.; off the coasts of New Jersey and Connecticut. Type specimens).

Jordan and Evermann 1896, p. 529. (Résumé of type description).

Norman 1930, p. 277. (4 specimens; 115 to 135 mm; 1025 to 2000 m[– 0]m.; about 1100 to 1400 miles off the coast of Argentina).

Roule and Angel 1933, p. 31. (1 specimen; 108 mm; 0 to 2000 m.; between New Scotland and Bermuda).

?Bathylagus elongatus:

Roule 1916, p. 8. (1 specimen; 158 mm; 1500 to 3500 m.; off Cape Finisterre, Spain).

Roule 1919, p. 22, pl. I, fig. 2. (Elaboration of the type description).

Bathylagus glacialis Regan 1933

Specimens taken by the Bermuda Oceanographic Expeditions

99 specimens; May to September, 1929 to 1931; 500 to 1000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; Standard lengths from 23 to 94 mm.

Specimens Previously Recorded

12 to 14 specimens; 100 to 1400 fathoms; North and South Atlantic and Antarctic Oceans; Standard lengths from 24 to 135 mm (Fig. 33).

Adult Specific Characters

(Fig. 34D)

Bathylagus glacialis is the only member of the family in which luminous tissue has been found. It is more slender than any of the other species in the genus except *B. gracilis, B. microcephalus* and *B. euryops.* From the first it is distinguished by its greater depth (6 to 6.3 in length, not 7 to 7.3), from the second by the longer head (4.1 to 4.6 in length, not 5.2 to 5.3) and from the last by the longer

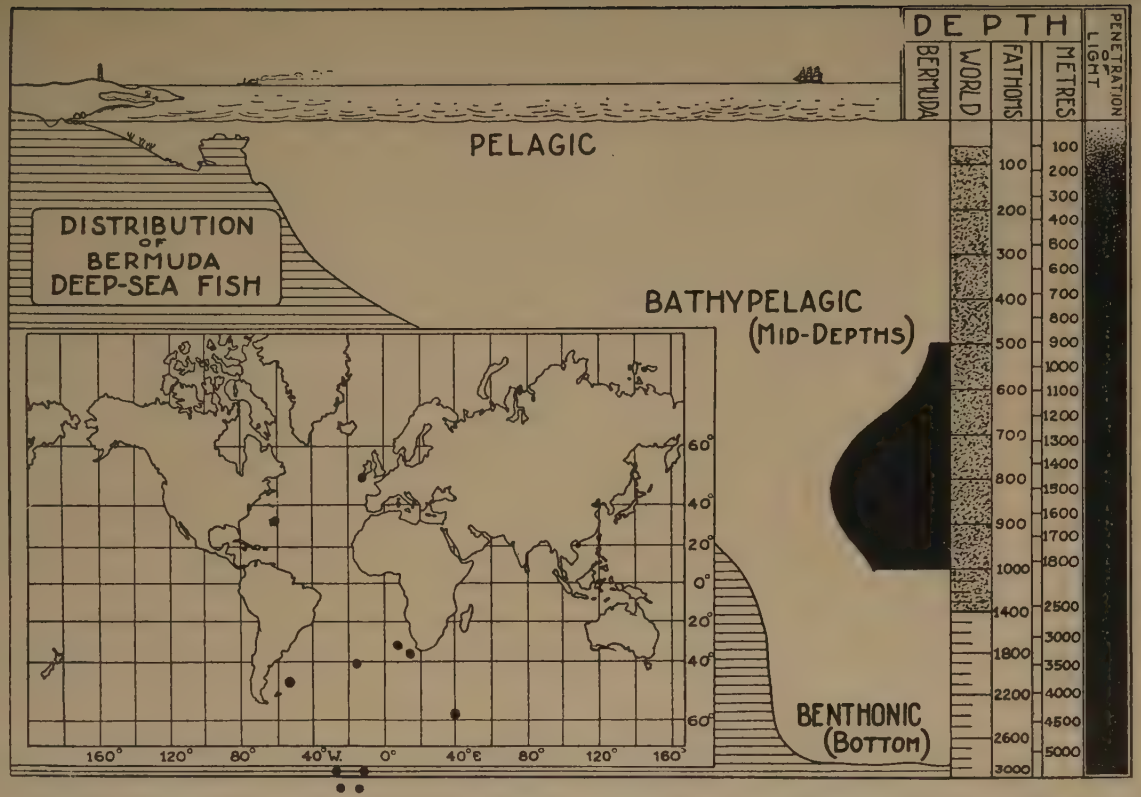


Fig. 33. *Bathylagus glacialis* Regan. The approximate geographical and vertical distribution of all recorded specimens. The relative number of specimens taken at different depths by the Bermuda Oceanographic Expeditions is shown diagrammatically at the right, for comparison with the previously known vertical range of this species.

anal base (not more than 6 in length, instead of 6.2 to 6.7). *Color:* Ground color cinnamon buff, with black chromatophores scattered on head and body beneath the outer epidermis. Lips, iris, opercles, coelom (showing through abdominal skin) and margins of scale pouches, black. The iris and opercles are frosted with silver in the fresh specimen, and the cheeks, isthmus, finbases and outer skin of the entire abdomen are white with a decided silvery sheen. In short, the general coloration closely resembles that of a typically pelagic fish, instead of a species entirely bathypelagic. Luminous material is present on the scales of the posterior part of the body, on the webs of the anal fin, and, sometimes, on those of the caudal. *Proportions:* Depth in length 6 to 6.3; head in length 4.1 to 4.6; eye in head 2.1 to 2.4; interocular in head 2.7 to 3; interorbital in head about 6; snout in head 5.3 to 5.5; origin of anal equidistant from base of caudal and insertion of pelvic or a little nearer the latter, 2.75 to 3.2 times as distant from tip of snout as from base of caudal; length of anal base about 6 in length of fish. *Finray Counts:* Pectoral 10; pelvic 8 to 9½, inserted below middle or posterior part of dorsal; dorsal 10; anal 18 to 21. *Teeth:* All uniserial; minute or absent on premaxillary and maxillary; larger on mandible, articulating with a series of about 12 similar pairs which form a continous semicircle on vomer and palatines. *Scales:* About 36 to 40 in a longitudinal row. *Gill-rakers:* 13 or 14 in the lower half of the 1st branchial arch.

Development

The Bermuda specimens of *Bathylagus glacialis* form a well graduated series consisting of post-larvae, adolescents, and several adults which are approaching full breeding condition. As will be seen below, there is some shrinkage during metamorphosis, the adolescent stage showing almost no increase in length. The three stages, though having distinct characteristics, are all perfectly linked through transition forms. The relation of these growth stages to standard length and numerical abundance is shown in the table on p. 117.

Egg: Well developed, round, white, opaque eggs were found in the ovaries of three specimens. In the largest (94 mm) they measured only .06 mm in diameter and reached an estimated number of 5200 in both ovaries. Small or undeveloped eggs were absent.

Larva: No examples of this stage were taken.

THE RELATION OF GROWTH STAGE TO LENGTH AND NUMERICAL ABUNDANCE IN BATHYLAGUS GLACIALIS

Length in mm	Larvae	Transitional Larvae	Post-larvae	Transitional Post-larvae	Adolescents	Transitional Adolescents	Adults	Total
23–24			1	2				3
25–26			2	10	12	1		25
27–28			4	6	23	1		34
29–30			1	3	13			17
31–32					1	3		4
33–34						2		2
35–36								
37–38								
39–40						3		3
41–42								
43–44						1		1
45–46						2		2
47–48								
49–50						1		1
51–52								
53–54							1	1
55–56							1	1
57–58								
59–60							1	1
61–62							1	1
63–64								
65–66								
67–68								
69–70								
71–72								
73–74							1	1
75–76							1	1
↓								
94							1	1
	—	—	—	—	—	—	—	—
			8	21	49	14	7	99

POST-LARVA: (Figs. 34A and 34B). Counting, as usual, the transition forms between post-larvae and adolescents as post-larvae, the Bermuda collection numbers 29 specimens of this growth stage measuring from 23 to 30 mm. It is briefly characterized by the pres-

ence of small, stalked eyes, partially developed paired fins and a greatly elongated adipose—the remnant of a dorsal finfold. A typical example is described below.

Trawling Data: All of the observations except those on the

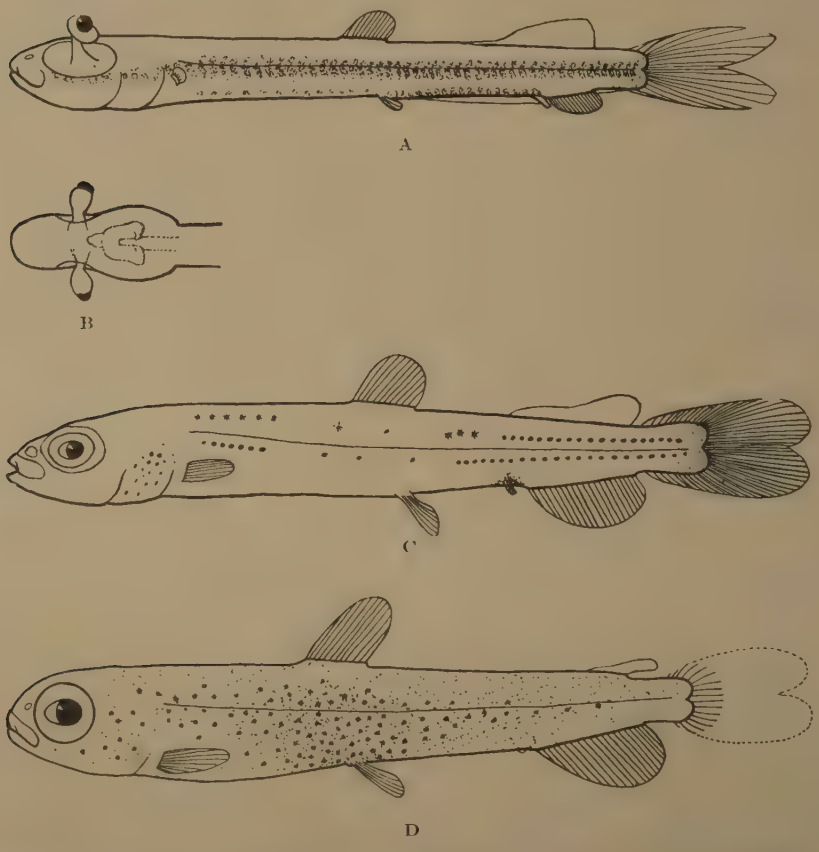


Fig. 34. *Bathylagus glacialis* Regan. A, post-larva, 23.5 mm.; B, same, dorsal view of head; C, adolescent, 30 mm.; D, adult, 94 mm.

skeletal system were made from the following specimen: Department of Tropical Research No. 22,546; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1193; Aug. 17, 1931; 7 miles south-east of Nonsuch Island, Bermuda; 500 fathoms; Standard length 23.5 mm.

Measurements and Counts: Total length 28.2 mm; standard length 23.5 mm; depth 2.1 (in length 11.2); head 5.7 (in length 4.1); eye 1 (in head 5.7); distance from center of pupil to dorsal rim of orbit 1.3; interorbital 1.1 (in head 5.2); snout to anal origin 19.9, the first finray 5.3 times nearer caudal base than tip of snout; anal base 1.6 (in length 14.7); dorsal rays 10; anal rays ca. 15.

External Characters: Pigment is practically lacking on the head, much of which is perfectly transparent, except for a smudge of black beneath the eye and another on the opercle. On the white body it is confined to two characteristic series—one above and one below the lateral line—of about 53 black blotches each, one pair to each myomere, the ventral one the darker. To each side of the ventral midline is a row of very black pigment spots extending from the pectoral base to the anal origin.

The dorsal and ventral profiles of the elongate, moderately compressed body are almost parallel from shoulder to caudal base, tapering but slightly in the region of the peduncle only. The bases of the fins are not elevated. The tip of the gut projects very slightly beyond the abdominal wall.

The head, viewed laterally, resembles a slight, almost symmetrical swelling on the end of the body; the snout is flattened and nearly horizontal, while the angle of the jaw, close beneath the orbital socket, scarcely projects at all. The small eyes are elevated on short, translucent stalks, similar to those found in a very young *Stylophthalmus*. The eyes themselves lack the outer, translucent capsule of the older fish, but the sockets which hold the stalks are relatively as much larger than the present diameter of the eye as is that of the adult fish. The nostril is small, far separated from its mate on the other side of the snout, closer to the orbit than to the tip of the snout. The maxillary reaches beyond the vertical from the anterior margin of the orbit.

The premaxillary, maxillary and palatine are toothless. In the mandible are 11 pairs of minute, close-set teeth in the anterior portion, followed by 9 pairs of larger ones, recurved, with small, even spaces between. The vomer holds three pairs of well developed fangs, curved, the outer two pairs the longest, all articulating with the anterior teeth of the mandible.

The gill membranes are perfectly united as in the older fish, and the gill openings characteristically small.

There are no scales whatever.

The pectoral consists of a fleshy basal pad with a fringe of short raylets, the true rays being as yet unformed. The pelvic reaches less than one-eighth of the distance between its insertion, under the middle of the dorsal, and the origin of the anal fin, and its rays are almost entirely undifferentiated. All of the rays of the dorsal are distinct, but the anal is shorter by three or four rays than in adult fishes. The caudal rays are well formed, with the tip of the urostyle protruding between the last rays of the dorsal caudal raylets and the first true, terminal rays. The dorsal adipose finfold is exceedingly long, nearly twice the length of the anal fin and extending from the vertical from the end of the anal almost half of the distance to the end of the dorsal. In depth it is relatively greater than the small adipose of the adult fish. The remains of a shallower finfold extend between the pelvic and anal origins.

There is no trace of luminous tissue.

Osteology: In an advanced post-larva (length 28 mm), the vomerine teeth, the jaws, angle of the quadrate, parasphenoid, and the margins of the opercles are quite strongly ossified, while the mandibular teeth, the urostyle and the proximal portions of the caudal rays show a moderate degree of ossification. None of the other bones show the least trace of it.

Digestive System: The alimentary canal is a simple, white tube extending from throat to anus close to the ventral profile. It is perfectly straight except for a short, z-shaped fold, the rudiments of the stomach, about 2 mm behind the plane of the pectoral fin.

ADOLESCENT: (Fig. 34C). The typically adolescent *Bathylagus glacialis* is characterized by having the eye unstalked, but still only one-half to three-quarters as large as in the adult, while the other proportions, development of scales and skeletal system are similarly immature. The most advanced specimens differ from the adult only in the immature condition of the gonads and the lack of ossification in a very few bones. Altogether, sixty-three examples of this stage were taken, measuring from 25 mm to 50 mm. Examples are described below.

Trawling Data: All characters except those of the skeletal system were described from the following specimen: Department of Tropical Research No. 16,948; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 761; July 2, 1930; 12 miles

south of Nonsuch Island, Bermuda; 900 fathoms; Standard length 30 mm.

The observations on the skeleton were made upon Nos. 15,149 (Cleared and Stained Collection No. 861), Standard length 54 mm; 15,518 (Cleared and Stained Collection No. 1063), standard length 31 mm; 16,507, (Cleared and Stained Collection No. 1151), standard length 31 mm.

Measurements and Counts: Total length 34.4 mm; standard length 30 mm; depth 4 (in length 7.5); head 7.8 (in length 3.9); eye 2 (in head 3.9); snout 1.7 (in head 4.6); maxillary 1.3 (in head 6); snout to anal origin 22, the first finray 2.8 times nearer the base of caudal than tip of snout; anal base 4.4 (in length 6.8); pectoral rays 10; pectoral length 1.9; pelvic rays 9½; pelvic length 2; dorsal rays 10; anal rays 19; caudal rays XII + 10 + 10 + XI; gill rakers 14.

External Characters: General color pale brown. Lips brownish black. Between lips and eye is a pale, translucent area nearly filled by the whitish narial tissue. Up the middle of the snout runs a narrow line of fine chromatophores, broadening in the interorbital region and ceasing abruptly above the middle of the eye. Behind this another translucent, whitish area reveals part of the brain. The isthmus is also translucent. The gill covers are heavily pigmented with fine, black pigment, much more deeply than the remainder of the fish, which is covered by large, interlacing, dendritic chromatophores which give a general effect of light brown. Above the lateral line there is a conspicuous row of larger spots and below it another, similar series. The proximal portions of the rays of the dorsal and pelvic fins are lightly pigmented; all of the other fins colorless, except for a zone of luminous tissue, white and frothy in appearance, which occupies the webs of the anal and lower caudal rays half-way to their tips.

The moderately elongate and compressed body tapers regularly from the shoulders to the base of the caudal, which is about half the maximum depth. The bases of the fins are scarcely elevated.

The crown of the head is almost level with the nape. The curve to the tip of the convex snout and equal lips is gradual, similar to that found between symphysis and preopercles.

The eyes show no trace of stalks externally, being firmly inserted in their orbits and fully sheathed by the transparent outer skin of the eye-ball. The diameter of the latter, just equal to that

of the orbit, is still considerably greater than that of the iris. The nostrils are enormous, almost filling the space between the orbit and the tip of the snout. The maxillary does not quite reach the vertical from the anterior margin of the orbit.

In the exceedingly thin premaxillary are very minute serrations, but no true teeth, while the maxillary lacks even the serrations. The mandible holds about 12 pairs of fine teeth. On the vomer are 2 pairs of stump-like teeth, neither as long nor as sharp as the corresponding ones in the post-larva. Palatine toothless.

Scales are present all over the body, but the majority are not imbricated. Those near the dorsal and ventral profiles, especially, are sometimes separated from the neighboring scales by their full diameter. The specimen is in such good condition and the scaleless places so smooth that it seems unlikely that many have been lost. Altogether, about half as many are present as in the adult. All are perfectly transparent ovals, like thin tissue in consistency, the edges of those on the abdomen loose and whitish, due to the partial development of luminous material. There are no radii, while circuli are indicated by about half-a-dozen exceedingly faint striations. The canal system is a miniature of that found in larger specimens except that the posterior border of each scale is excavated into a deep scallop which extends almost to the central pore. A typical lateral line scale taken at the vertical from the anal origin is .54 mm long by .38 mm broad. A normal scale from the same vertical two rows below the lateral line measures 1.08 mm by .7 mm.

The rays of the paired fins are all well developed. The pelvics reach more than one-fourth of the distance between their insertion and the anal origin, and arise at the vertical from the 7th or 8th dorsal ray. The dorsal originates mid-way between snout and caudal base. The anal and caudal are fully developed. The adipose is as long as the anal fin, with traces of finfold remaining even further forward, almost to the end of the dorsal. Similar traces of the ventral finfold are found in front of the anal.

Half-way to the tips of the anal rays is a zone of white and frothy luminous tissue, occupying the webs. Traces of this continue across the most ventral raylets of the caudal fin, dying out just beyond the base of the true caudal rays. The scales of the lower sides are also bordered with a luminous substance.

Osteology: In a typical adolescent of 31 mm the head and opercles are fairly well ossified; the anal fin, the caudal and the urostyle faintly. A specimen of the same length, but with external characters showing it to be in the transition stage between adolescent and adult, has all of the above areas much more strongly ossified, the paired fins moderately so, and the anterior part of the vertebral column faintly. A larger immature specimen of 54 mm has the entire skeleton ossified with the exception of the tips of the finrays, the girdles of the pectoral and pelvic fins and the 14 anterior, rayless baseosts (described on p. 135).

Digestive System: The alimentary canal differs from that of the adult (Fig. 42) in three ways: the stomach is proportionately shorter, its first, most dorsal section alone is pigmented and this is comparatively pale, and the caeca are short rudiments. Coelom, dark brown.

Reproductive System: The gonads occupy the same relative position as in the adult, against the dorsal wall of the coelom, but are almost invisible, being flat, exceedingly narrow and perfectly transparent.

ADULT: (Fig. 34D). Seven fully adult specimens were taken off Bermuda measuring between 54 mm and 94 mm. The stage is characterized by completely developed bodily proportions, ossification and gonads. The largest of the Bermuda specimens, a female, is described below.

Trawling Data: Department of Tropical Research No. 11,508; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 290; July 11, 1929; 9 miles south-east of Nonsuch Island, Bermuda; 1000 fathoms; Standard length 94 mm.

Measurements and Counts: Standard length 94 mm; depth 16 (in length 6); head 21 (in length 4.6); eye 8.6 (in head 2.4); snout 3.9 (in head 5.4); interocular 7 (in head 3); interorbital 3.6 (in head 5.8); maxillary 5 (in head 4.2); snout to anal 72; the first finray 3.2 times nearer base of caudal than tip of snout; anal base 16 (in length 6; adipose base 1.2 (in anal 13.3); pectoral rays 10; pectoral length 10.7; pelvic rays 9, origin under 7th dorsal ray; length longest pelvic ray 8.6; dorsal rays 10; anal rays 19; caudal rays XI + 10 + 10 + XII; about 40 scales in a longitudinal series; 16 gill-rakers on lower half of first gill arch.

External Characters: Ground color cinnamon buff, with a silver sheen ventrally. The under layers of epidermis, beneath the

blackish-edged scale pouches, are thickly speckled with dark brown, slightly dendritic chromatophores. The lips, orbits and coelom wall (visible externally through the abdominal skin) are black. The iris and opercles are also black, but densely frosted with silver. Luminous bands on fins, silvery white.

The moderately elongate body is considerably compressed. Deepest at the shoulders, it tapers gradually to the caudal base, which is less than half of the greatest depth. The fin bases are all slightly elevated.

The general contour of the top of the head is low and rounded. The apex is on a level with the nape and shoulders, the interorbital region somewhat depressed and the short snout convexly curved to the protruding upper lip. Beneath this the lower jaw slants sharply downward and back to its angle at the vertical from the anterior margin of the eye. From here to the pectoral origin the oblique descent of the nearly straight ventral profile is more gradual. The diameter of the eye is less than the length of the postorbital region, its upper margin elevated above the cephalic profile. Socket of eye ball elliptical. The nostrils are placed close to the orbit, separated from each other by the breadth of the snout. The gape slopes sharply downward and back, the maxillary extending to the vertical from the anterior margin of the eye.

Teeth are present in the maxillary, mandible, vomer and palatine. The premaxillary is quite toothless, but has microscopic serrations. In the maxillary a few true teeth, very minute, are scattered. The mandible holds about 25 pairs of tiny teeth, close-set, nearly straight, and of an almost constant diameter. These articulate with the teeth of the vomer and palatine of which there are altogether 12 pairs.

There are numerous pores on the head, arranged in single series along the jaws and isthmus and in a double circle around the eye. They open into a network of canals, presumably part of the lateral line system, which is partially traceable through the thick, translucent, outer epidermis of the head.

Most of the scales are missing, but judging from the pouches, the scales in the anterior part of the body and on the opercula were three or more times the size of those at the caudal base. There were at least 40 scales in the lateral line and six rows, exclusive of the profile rows and those along the bases of the dorsal and anal fins.

Scaled areas: The fish is entirely scaled behind the vertical from the posterior border of the lens of the eye.

Number and arrangement: Due to the loss of many of the scale pouches, it is impossible accurately to count the scales of each row, but the total number is about as follows, excluding those of the head:

Paired scales (ca. 250 x 2)	500
Unpaired scales (dorsal and ventral profiles)	40
Total	540

Each row extends straight from the nape or opercle to the caudal base.

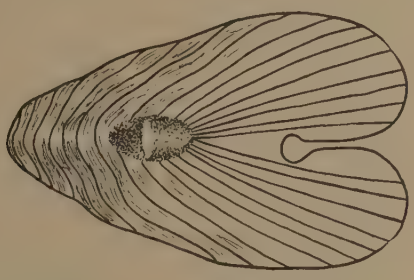


Fig. 35. *Bathylagus glacialis* Regan. Lateral line scale from above anal origin. From an adult specimen, 94 mm. in length. (× 20).

All of the scales on the 94 mm specimen were missing, but a few, well imbricated, remained along the lateral line of a 60 mm fish (No. 17,534). The one illustrated (Fig. 35) is about the 23rd in the lateral line, from the vertical from the anal origin. It is broadest anteriorly, and measures 2.7 mm in length by 1.7 mm maximum breadth. There are 7 or 8 circuli, running around the scale anteriorly, but in the apical portion they extend straight backwards, parallel to the dorsal and ventral borders.

The pectoral fins are inserted very close to the ventral profile, the rays bifid from the base, and the longest of them extending over about a quarter of the distance between their origin and that of the pelvics. The rays of the latter are also double, and of about an equal length, the longest reaching a third of the way between the pelvic and anal origins. The dorsal fin commences nearer the snout than the caudal base. The distance from the anal origin to the base

of the caudal is about equal to that between the pelvic and anal origins. Adipose inserted opposite the posterior anal rays.

The skin of the abdomen, the proximal portions of the anal and lower caudal rays are covered with a thin coating of frothy, silvery white, luminous material.

Osteology: A specimen (No. 13,585) measuring 74 mm in length is strongly ossified; its detailed description follows.

Skull: (Figs. 36 and 38). In general the bones of the head are well ossified but exceedingly delicate. Most of them are of similar thickness throughout, with few ridges or areas of more deeply concentrated bony tissue, the principal exceptions being the angle of the quadrate, the hyomandibular, the opercles and the branchiostegal rays.

From above, the broad and flattened cranium is divided into three general areas. The most posterior, or cranium proper, includes the entire postorbital region and is dominated by the large, central, quadrilateral supraoccipital. Somewhat broader than long, it extends back into a short spine above the deeply imbedded atlas, and in front as far as the plane of the end of the orbit. It is bounded posteriorly by the triangular epiotics and anteriorly by the parietals, of similar shape to the epiotics and touching them lateral to and below the supraoccipital. The oval pterotics are visible from above, below the parietals and posterior to the sphenotics.

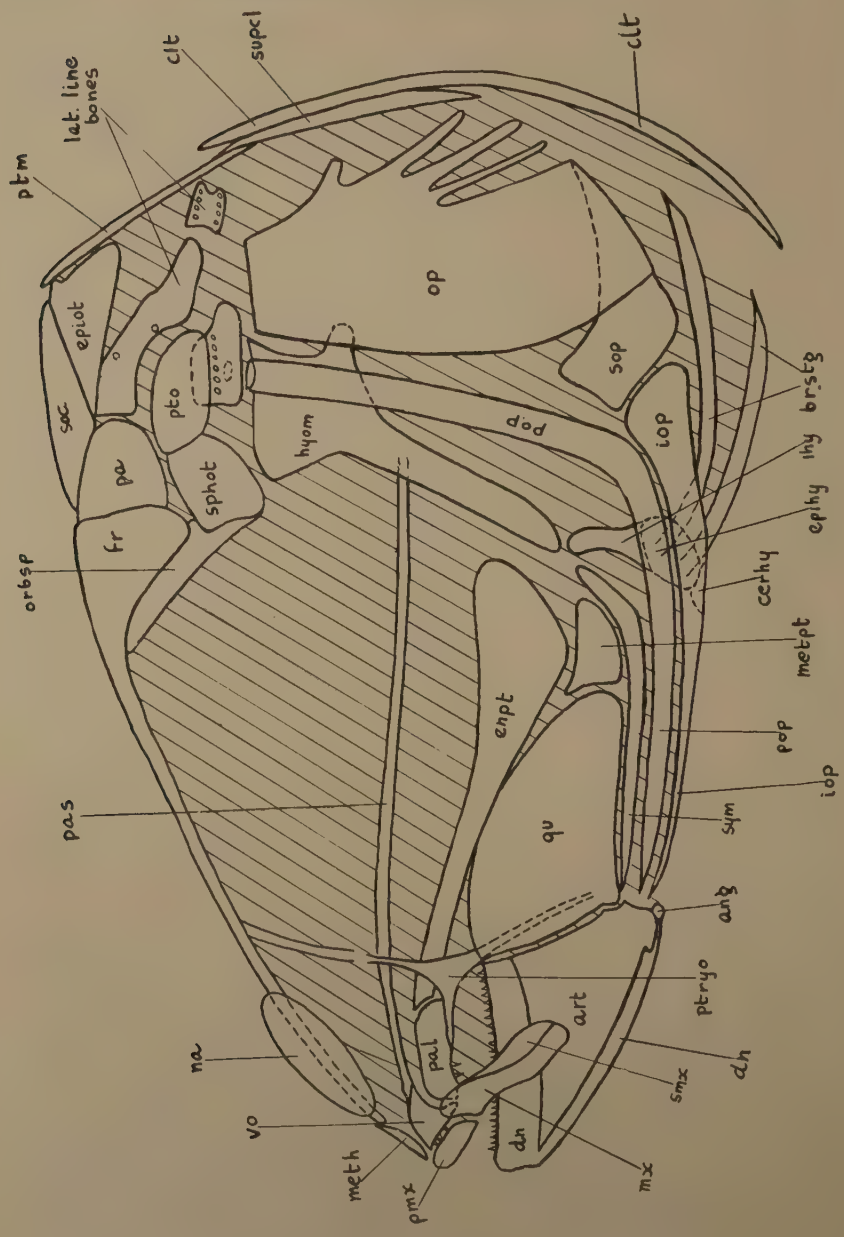
The median section of the cranium covers the whole of the interorbital region and is twice as large as either the postorbital or antorbital section. The broadly expanded, fused frontals occupy two-thirds of the space, the supraorbitals and postfrontals the remainder. The posterior border of the frontal is almost straight, lying between the posterior extension of the postfrontal, contiguous to the sphenotics and parietals, but not in contact with the supraoccipital. Laterally, the frontals have broad margins bent upwards to encase the ocular tissues, which project above the level of the rest of the head and are surmounted by the broad, leaf-like postfrontals and the supraorbitals, over twice as long as the first bones. The prefrontals extend downwards along the anterior margin of the orbit, directly beneath the anterior part of the supraorbitals.

The leaf-like nasal bones occupy most of the length of the preorbital region of the dorsal aspect of the skull. They are superficial and close together, separated only by the narrow tongue which is

the anterior extension of the frontals. This tongue ends in a forked tip close beneath the apex of the triangular metethmoid. The base of the latter is separated from the slenderly curved premaxillaries by a definite gap. Maxillaries, palatines, entopterygoid and pterygoids can be seen deeper down in the broad snout, far lateral to the nasals.

Palato-pterygoid arcade: The deeply imbedded hyomandibular commences dorsally beneath the sphenotic and pterotic, sending off a short, posterior arm to articulate with the opercle, interior to the upper, anterior margin of the latter. Then, well behind the orbit, a long, rather slender arm extends in an obliquely ventral direction and ends in front of the angle of the preopercle, above the interhyal and tip of the symplectic. The latter bone is an elongate shaft, straight except for the upturned, posterior end, which bounds the small metempterygoid posteriorly and ventrally and the large, fan-shaped quadrate along its entire lower edge. Both metempterygoid and quadrate are inclined sharply inwards, and are overlaid by the jugal, as subsequently to be described. Above and interior to them the elongate, posteriorly expanded entopterygoid forms the roof of the gullet. Anteriorly it joins the oblong palatine, which in turn connects with the vomer in front and the pterygoid laterally. The pterygoid is a triangular bone with three slender spines: The anterior joins the palatine; the most dorsal runs upward, exterior to the entopterygoid, along the anterior margin of the orbit, almost meeting the prefrontal; and the third and largest extends postero-ventrally behind and in contact with the anterior portion of the quadrate, terminating just above the articulation of the jaw. The slender parasphenoid runs from the vomer back through the center of the head, between the eyes, with a slight upward curve in its anterior portion.

Jaw apparatus: The premaxillaries, although entirely edentulous, are well ossified, not fused in the midline nor touching any of the surrounding bones. The maxillaries, likewise without teeth but deeply stained, extend obliquely downward, exterior to the middle of the solidly constructed dentary. The articular, with boundaries very faintly marked, occupies almost the entire space between the V formed by the dorsal, toothed side of the dentary and its antero-ventral boundary. The angular is minute and rounded, well below the junction of the articular with the quadrate. The mandibular teeth are ossified only at their bases; the larger ones of vomer and palatine throughout their lengths.


clt
supcl
clt
lat. line bones
ptm
epiot
sac
pto
op
sop
iop
hyom
d
d
sphot
par
fr
orbsp
ephy
brstg
ihy
cerhy
metpt
pop
enpt
qu
sym
iop
pas
ang
ptryo
art
dh
smx
pal
na
vo
dn
meth
pmx
mx

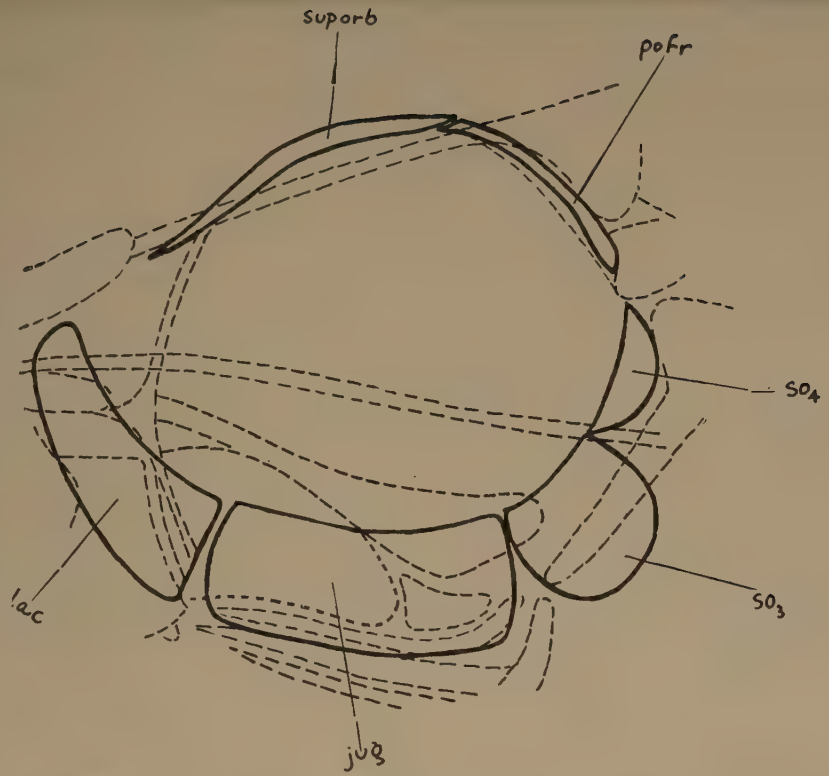


Fig. 36. (*Above*). *Bathylagus glacialis* Regan. Skull, hyoid arch and opercular bones, lateral view. The circumorbital bones have been omitted.

Fig. 37. (*Below*). *Bathylagus glacialis* Regan. Circumorbital bones. The broken lines indicate the boundaries of the underlying bones depicted in fig. 36.

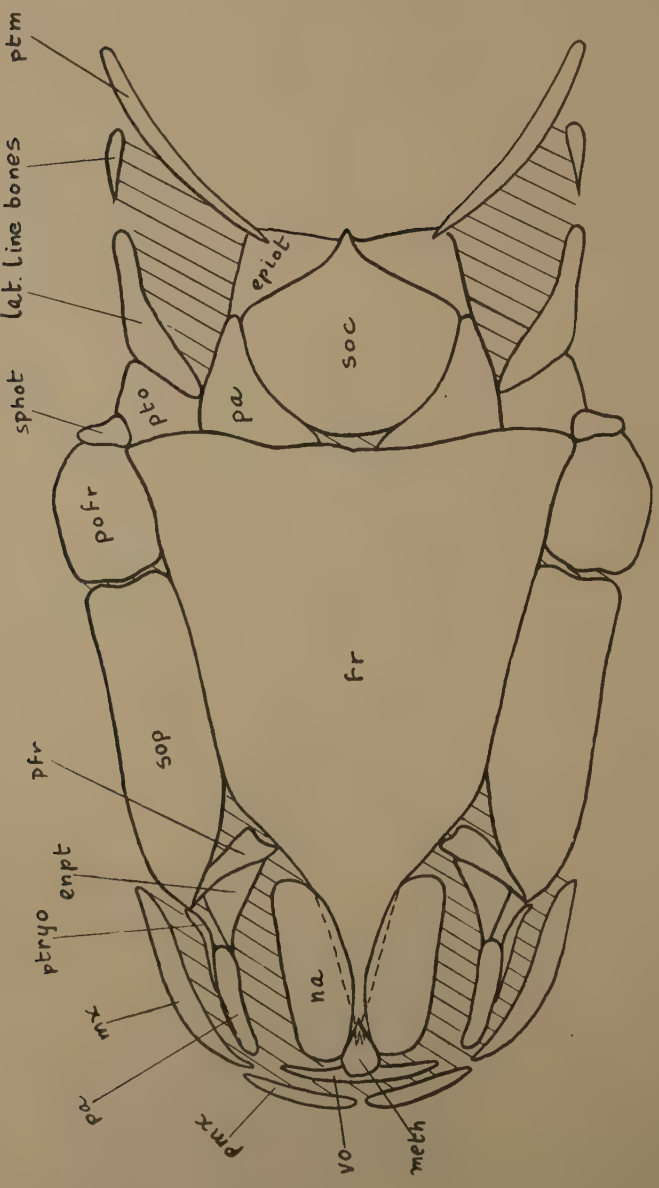


Fig. 38. *Bathylagus glacialis* Regan. Skull, dorsal view.

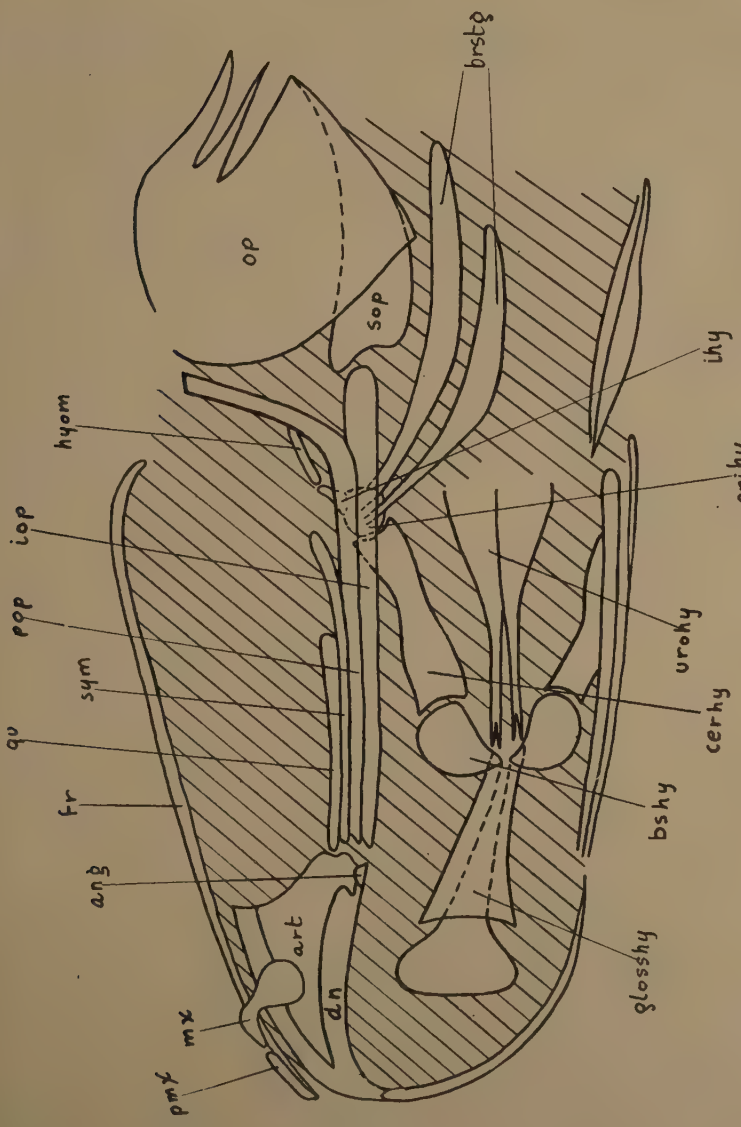


Fig. 39. *Bathylagus glacialis* Regan. Skull, hyoid arch and opercular bones, latero-ventral view.

Opercular bones: Preopercle, interopercle and subopercle are all strongly ossified and comparatively sturdy; the opercle on the other hand is but lightly stained and very fragile, especially posteriorly, except for the margins of three to six posterior, comb-like ridges which extend obliquely downward. These are more numerous on the right side of the fish than on the left. The posterior part of the subopercle lies just interior to the opercle, its anterior portion filling the space between the opercle and the expanded head of the interopercle. The latter extends forward as a thin, exceedingly elongate bone beneath and partially interior to the corresponding part of the preopercle, both ending barely in back of the articular. Posteriorly the preopercle curves almost straight upward between opercle and hyomandibular, passing exterior to the short, posterior branch of the latter and terminating level with the top of the opercle. At this point it is seen that at least the upright arm of the preopercle is quite hollow, with the end almost in contact with an unidentified, poriferous bone.

Cephalic bones of the lateral line: The poriferous bone just mentioned has its dorsal portion lying interior to the pterotic and all of it is well imbedded in the tissues; there is little doubt but that it belongs to the lateral line system. There are two other bones, similar in character but lying almost on the surface and quite unconnected with the cranium. The first, a narrow oblong, lies between epiotic and pterotic. The second, small and oval, extends between the first bone and the origin of the lateral line proper, above the opercle. Both are well ossified, the longer one having several irregular pores, the smaller showing four pairs of perforations along the dorsal and ventral edges.

Circumorbital bones: (Fig. 37). Due to the great size of the eyes, the supraorbital and postfrontal, as already described, roof rather than border the eye-ball, while the circumorbital bones have been pushed down exterior to the bones of the palato-pterygoid arcade. All are greatly expanded, delicate, superficial and only moderately well ossified. The lacrymal is an extensive oblong, its anterior, upper end overlying the posterior part of the upper jaw, its vertical and posterior the articular as far as the jaw angle. The jugal covers as much distance externally as do both quadrate and metempterygoid inside, and reaches from the orbit to the vertical arm of the preopercle. Dividing the space between the jugal and

the small sphenotic there are but two circumorbitals; a broad one extending across the hyomandibular to the vertical preopercular arm and a small, semicircular plate, dorsal to this and not reaching the hyomandibular. A moderate-sized orbito-sphenoid lies interior to sphenotic and frontal.

Hyoid arch: (Fig. 39). The tip of the short and rather slender interhyal thrusts up between the symplectic and the hyomandibular, wihle its lower end is in contact with the rounded epihyal. From the latter bone arise the two flat, slightly curving branchiostegals; each of these has a low, median keel. The spindle-shaped ceratohyal is four times the length of the epihyal and almost touches the basihyal. The basihyals are slightly longer than broad, with pronounced ridges opposed to each other and nearly in contact across the ventral midline. Passing beneath these bones toward the basibranchials is the stem of the large glossohyal, a deeply imbedded, cone-shaped, feebly ossified bone with its base in about the same plane as the posterior part of the maxillary.

Pectoral girdle: The slender post-temporal is attached dorsally to a short spine on the lower, posterior corner of the epiotic. Post-temporal, supracleithrum and cleithrum all articulate at about the level of the dorsal rim of the opercle, the top of the supracleithrum lying wedged between the ventral tip of the post-temporal and the dorsal end of the cleithrum. The supracleithrum, always anterior to the cleithrum, reinforces it as far down as the lower third of the opercle, where it terminates. The cleithrum continues ventrally in a broad curve. The bone is twisted and folded throughout its length, with several lateral expansions. The shape of the large and thin post-clavicula cannot be exactly determined, as it is only feebly ossified, and this in patches only. Three pterygials are moderately well ossified.

Vertebral column and fins: (Fig. 40). The vertebral column and all its appendages are strongly ossified. Including the axis and urostyle there are 53 vertebrae. These are of similar size (1.4 mm long by .7 mm minimum diameter) as far back as the posterior part of the anal. Posterior to this they are slightly smaller.

The axis has a short, neural protuberance only. Following this are two vertebrae without ribs but similar in every other way to the succeeding 28, ribbed elements. In these the neurapophyses are

not united as far back as the 26th vertebra, well behind the end of the dorsal fin; they arise from the anterior part of the centrum as a

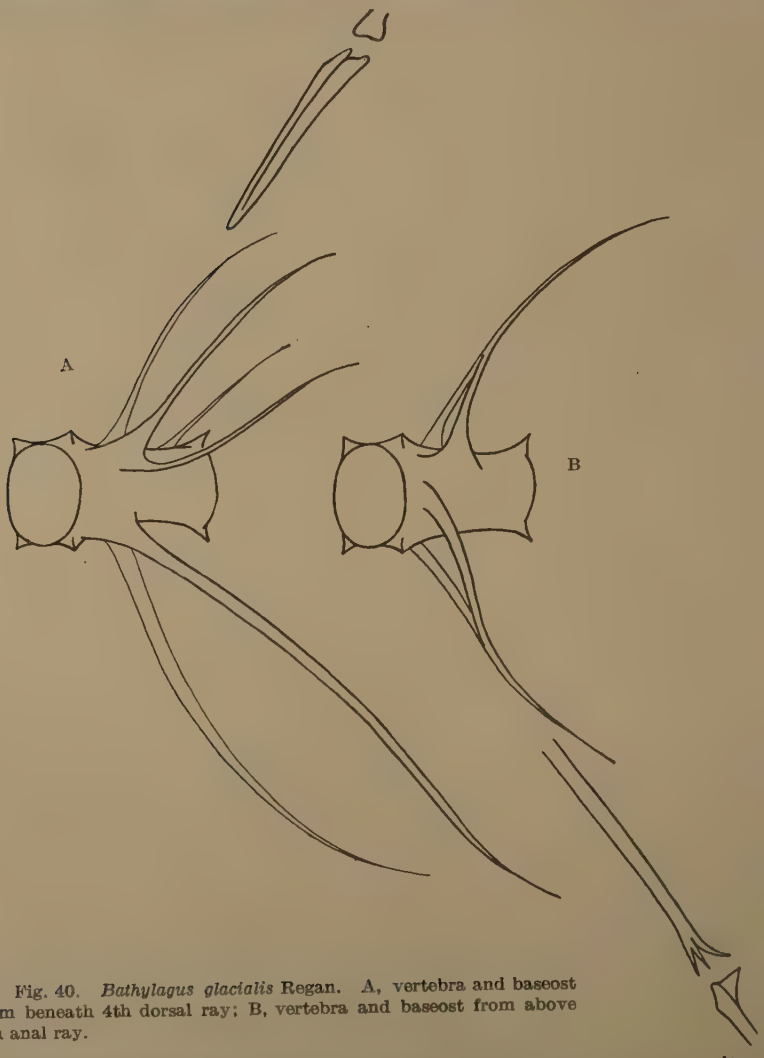


Fig. 40. *Bathylagus glacialis* Regan. A, vertebra and baseost from beneath 4th dorsal ray; B, vertebra and baseost from above 7th anal ray.

pair of slender spines, about twice as long as the centrum itself. From the 26th on, however, the distal two-thirds of each pair are fused, forming typical neural arches. From their bases arise ex-

ceedingly delicate epipleural spines, directed outwards and back, four-fifths the length of the entire neural element. There is no trace of a haemal arch in front of the 27th vertebra; at this point, however, a pair of tiny, short spines is visible at the front of the parapophyses. At the 29th, they are much larger and unite in the median line, forming a complete haemal arch with a short haemal spine. Several vertebrae behind this the spine lengthens to equal the neural spine; the succeeding ones are similar, until the first modifications of the caudal base appear (see below).

Ribs are found on the third through the thirty-second vertebrae inclusive. They arise from broad parapophyses far down on the sides of the anterior halves of the centra. Normally they are about twice as long as the neurpophyses, but the last six are progressively reduced in size and their origins shifted gradually outward along the haemal arch.

Anterior and posterior zygopophyses are well developed.

There are 14 dorsal baseosts which lack finrays. The first is very small and close to the second, both anterior to the first neural spine, arising from the first vertebra back of the atlas. Close in front of the base of the first dorsal ray three baseosts radiate, the first two short and pointing forward. These three exactly make up the number to fill the three empty inter-neural-spine intervals to the fourth, which is the normal baseost of the first dorsal ray. This undoubtedly is a degenerate condition, reflecting an ancestor which must have had a strong, continuous fin from the neck backward. These extra baseosts are the last bones in this species to show traces of ossification, although they are as strongly ossified as the succeeding baseosts in the present specimen. There is a single baseost for each dorsal ray, extending downward from the finray base in front of and between the tips of each pair of neural spines. In the anal fin the first and last rays, very short though strongly ossified, lack support; otherwise one baseost is opposed to each ray. All of the baseosts have thickened cores, four-pointed dorsal tips and delicate, lateral flanges.

Caudal fin and end of vertebral column: (Fig. 41). The first vertebra to show any caudal specialization is the 46th or seventh before the urostyle. This and the succeeding one have the neural and haemal spines lengthened, and articulating with the anterior caudal raylets. The 48th in addition shows a slight,

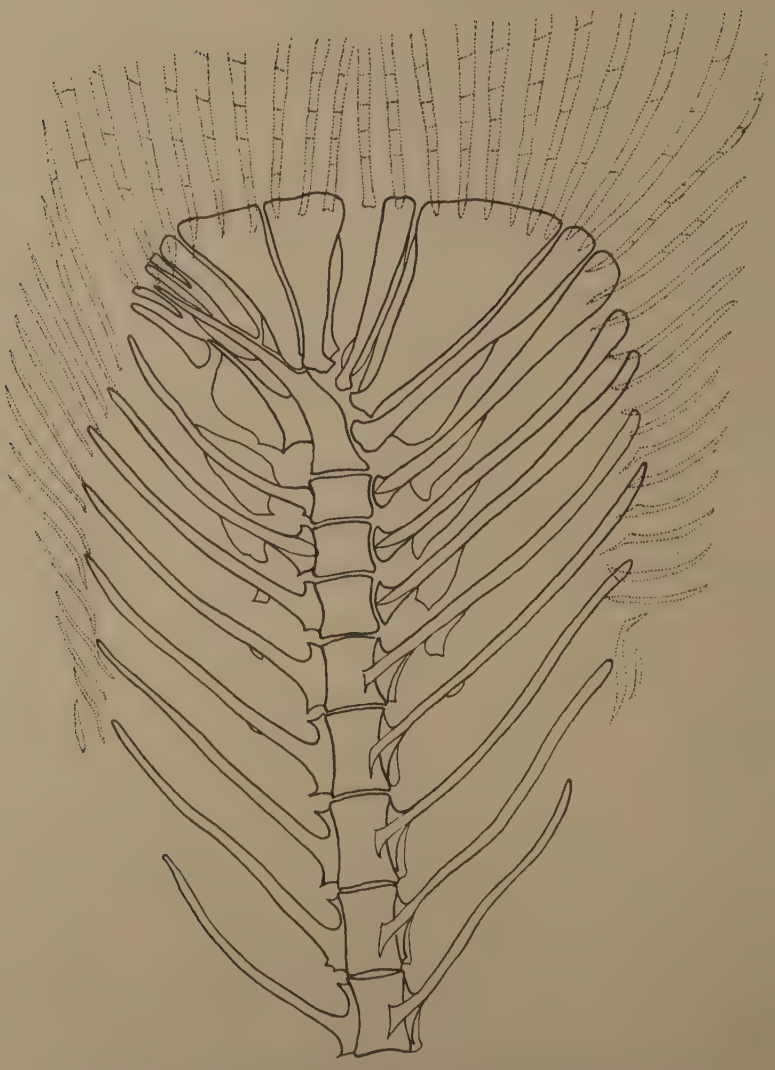


Fig. 41. *Bathylagus glacialis* Regan. Caudal vertebrae and finrays. (Preparation and drawing by Gloria Hollister)

median, anterior keel of bone at the base of the spines. This incurves to a wide and elongate bony wing on the succeeding four

vertebrae, the neural spine of the last showing the keel developed on both central and posterior sides of the spine.

The urostyle extends far up and back, almost to the epural, neural-spine contour. It bears on the anterior side near the bone an elongate, enlarged neural arch and spine having a wide, thin keel. There are two epurals, the anterior twice as long and wide inferiorly as its fellow. In the ventral aspect of the urostyle we count eight hypurals, the first very similar to the preceding hypaxial element. The second hypural (1.9 x .9 mm) is the largest bone in the caudal complex, twice as long as it is wide posteriorly. The third hypural is narrow and closely connected with the second. The fourth is wide and parallel with the vertebral column and almost as great in extent as the fifth. The sixth is much smaller, but elongate and flattened, while the seventh and eighth hypurals are small splinters of bones like the epurals.

The sequence of external elements is XIII + 10 + 12 + 13.

The anterior five dorsal raylets are sloped more and more sharply forward, but only the two anterior ventral raylets are thus specialized, lying horizontally, almost at right angles to the remainder.

Digestive System: (Fig. 42). The following measurements were taken on a specimen of 75 mm (No. 17,534): Oesophagus and

Fig. 42. *Bathylagus glacialis* Regan. Alimentary canal.

stomach to its most posterior extent, 18.6 mm long, 2.9 mm in diameter; pyloric canal (from posterior end of stomach to base of caeca) 13.9 mm long, 1.1 mm in diameter; intestine 68.9 mm, equal in average diameter to the pyloric canal except immediately posterior to the middle of its length, where there is a short portion somewhat swollen. There are six caeca, the longest measuring 4.3 mm in length, the shortest 2.9; diameter of the longest, .7 mm. The liver is bi-lobed, each half measuring 4.3 mm long by 2.9 mm in maximum breadth. Coelom, oesophagus, stomach and pyloric canal, jet black; intestine and caeca, white.

Reproductive System: In the female of 94 mm the ovaries lie against the dorsal wall of the coelom and are about 50 mm long by .65 mm broad. They are very flat, with the minute eggs arranged in single, double and triple layers.

A female of 60 mm with unripe eggs was taken in the same net as a 75 mm male. The testicles of the latter exactly correspond in relative size and position to the ovaries of the female, and seem about spent.

SUMMARY OF DEVELOPMENT: The following résumés of the characteristics of each growth stage are based on a study of all of the specimens in the Bermuda collection.

Summary of the Changes Taking Place During Growth

Post-larva: 23 to 29 mm. Two characteristic rows of lateral pigment spots, one above and one below lateral line; body slender (depth in length 10 to 11.5, not 6 to 6.3 as in adult); eyes stalked, small; vomerine teeth 1 or 2 pairs; no palatine teeth; no scales; pectoral rays undifferentiated; pelvic reaching about one-eighth of distance between insertion and anal; anal with from 1 to 4 rays fewer than adult; urostyle tip prominent; adipose finfold much longer than anal base; traces of pre-anal finfold; extreme tip of gut projecting; ossification absent or present only on jaws, quadrate angle and opercular margins.

Transition: 23 to 30 mm. Eye sunk into orbit, but smaller than latter and not attached to either its rim or sides; one or more other post-larval characters remaining combined with those of the adolescent, given below.

Adolescent: 25 to 31 mm. Post-larval pigment spots persisting; body approaching adult depth (depth in length 6.8 to 7.4, not 6 to 6.3 as in adult); eyes firmly attached to orbit, but with the iris small, the whole encased in a thick, transparent membrane, the entire diameter of which is contained only about 4 times in the head (instead of 2.2 to 2.4, as in the adult), and is considerably less than the length of the post-orbital region; vomer and palatine with 2 to 4 pairs of teeth altogether, smaller than in post-larva; scales developing; finrays all well developed; pelvic extending over one fourth to one-half of the distance between its insertion and the anal origin, having 9 or 10 rays; urostyle tip almost invisible; adipose finfold about equal to anal base,

except for occasional traces, very shallow, further forward; tip of gut may project; ossification partial (head and proximal parts of finrays only).

Transition: 26 to 50 mm. Like adult, except that there are 6 or more (but not 12) pairs of vomerine and palatine teeth alto gether, the two lateral rows of pigment spots persist, ossification is incomplete, gonads immature, and luminous tissue generally undeveloped.

Fathoms	May			June			July			Aug.			Sept.			Total		
	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931
500		2						1				1					3	1
		2						1			1						4	
600	2	1					2		2			2				4	1	3
		3						3			2						8	
700		1			3			3	1			3	4	4	2	4	11	6
		1			3			4			3			10			21	
800		2		3	6		1	1				3	1	5	4	5	14	7
		2			9			2			3			10			26	
900				1	3		3	5		2			3	5	1	9	13	1
					4			8			2			9			23	
1000				1			2			5		1	7	1		15	1	1
					1			2			6			8			17	
Total	2	6		5	12		8	10	2	7		10	15	15	7	37	43	19
		8			17			20			17			37			99	

Fig. 43. *Bathylagus glacialis* Regan. The vertical, monthly and yearly distribution of the specimens taken by the Bermuda Oceanographic Expeditions.

Adult: 54 to 94 mm. Depth in length 6 to 6.3; eyes contained 2.2 to 2.4 times in head, equal to or larger than post-orbital region; vomerine and palatine teeth about 12 pairs altogether; scales and luminous material fully developed; pelvic extending over more than one-half the distance between its insertion and anal origin; sometimes a vestigial tenth ray found in pelvic fin; urostyle entirely internal; adipose finfold lacking, the adipose fin being but a small fraction of the anal base in length; tip of gut not projecting; ossification complete; gonads mature.

ORDER OF DEVELOPMENT OF PRINCIPAL CHARACTERS

KEY:

..... Development rudimentary.

---------- Half developed

———— Fully developed (i. e. in regard to appearance and proportions, but not in actual size).

	LARVA	*POST-LARVA*	*ADOLESCENT*
Number of Specimens	29	63	7
Locality	Bermuda	Bermuda	Bermuda
Season	June to Sept.	May to Sept.	May to Sept.
Vertical Distribution	500 to 1000 F.	500 to 1000 F.	700 to 1000 F.
Length	23 to 30 mm	25 to 50 mm	54 to 94 mm
Growth Characters			
Finfolds	.....	.....	
Post-larval pigment	————	————	.....
Dorsal fin	————	————	————
Caudal fin	————	————	————
Anal fin	----------	————	————
Pectoral fin	----------	————	————
Pectoral fin	----------	————	————
Body form	----------	————	————
Eyes	.....	.....	————
Mandibular teeth	----------	————	————
Vomer and palatine teeth	.....	.....	————
Alimentary canal	.....	.....	————
Ossification of skull		----------	————
Scales		.....	————
Ossification of fins		.....	————
Gonads		.....	————
Luminous tissue		.....	————
Ossification of vertebrae		.....	————
Ossification of girdles			————

Ecology

Vertical and Seasonal Distribution: Fig. 43 shows the vertical, monthly and yearly distribution of the Bermuda specimens of *Bathylagus glacialis*. The vertical range lay between 500 and 1000 fathoms, with a mean depth of 808 fathoms. Even on the basis of an equal number of nets each month, the species was rare in the spring, most abundant in September (Figs. 44 and 45). The world distribution map (Fig. 33) shows the Bermuda depths side by side with those of the specimens previously recorded, for purposes of comparison.

The table below correlates the data of the graphs just mentioned with length and growth stage (discussed under Development) and gives in addition average depths and lengths:

Relation of Month, Number of Specimens, Depth, Length and Growth Stage

Month	Number	Depth in Fath.: Extremes	Average	Length in mm: Extremes	Average	Growth Stages
May	8	500–800	638	26 to 55	31.5	Adolescent Adult
June	17	700–1000	818	25 to 46	33.1	Post-larva Adolescent
July	20	500–1000	795	25 to 94	33.1	Post-larva Adolescent Adult
Aug.	17	500–1000	824	23 to 30	27.2	Post-larva Adolescent
Sept.	37	700–1000	841	24 to 75	31.9	Post-larva Adolescent Adult
Total	99	500–1000	808	23 to 94	31.5	Post-larva Adolescent Adult

Much of the data of this table is presented in graph form in Fig. 46. A study of both table and graph results in the following conclusions:

1. In Bermuda *Bathylagus glacialis* is taken on an average of more than 100 fathoms higher in the spring than in late summer and fall.

2. Specimens in all stages of growth, beginning with the post-larva and ending with adults in almost full breeding condition, were

taken from May to September, showing no evident correlation with depth or season.

SOCIABILITY: In two nets three specimens were found together; in eight, two immature fish; and in one net, a pair of young adults, male and female, not in breeding condition.

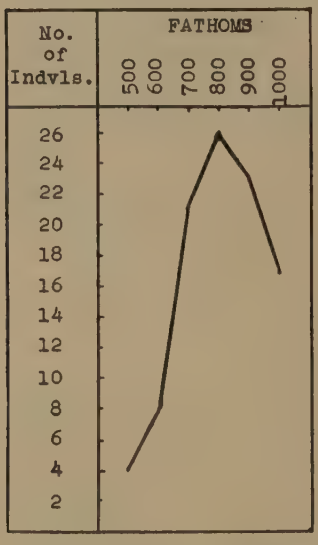


Fig. 44. (*Left*). *Bathylagus glacialis* Regan. The vertical distribution of the specimens taken by the Bermuda Oceanographic Expeditions.

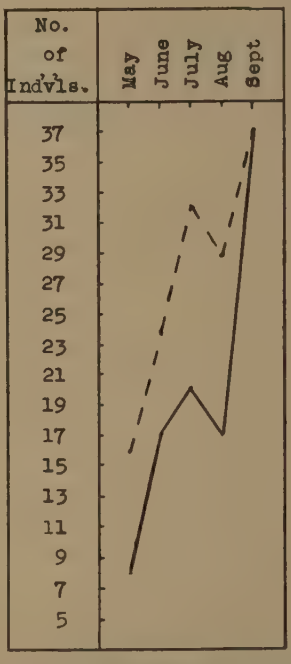


Fig. 45. (*Right*). *Bathylagus glacialis* Regan. The seasonal distribution of the specimens taken by the Bermuda Oceanographic Expeditions. The solid line is based upon the actual number of specimens taken, the broken line upon the number which would theoretically have been caught if as many nets had been drawn every month as during September.[1]

ABUNDANCE: *Bathylagus glacialis* is uncommon among the deep-sea fishes taken off Bermuda. It occurred in 9.5 per cent of all the nets drawn between 500 and 1000 fathoms, the limits of its vertical distribution.

FOOD: The stomachs of ten specimens, measuring from 30 to 96 mm were opened. All were entirely empty, with one exception, a 64 mm fish whose stomach contained a single copepod. The specimens examined were taken between 600 and 1000 fathoms.

[1] See Introduction, p. 7.

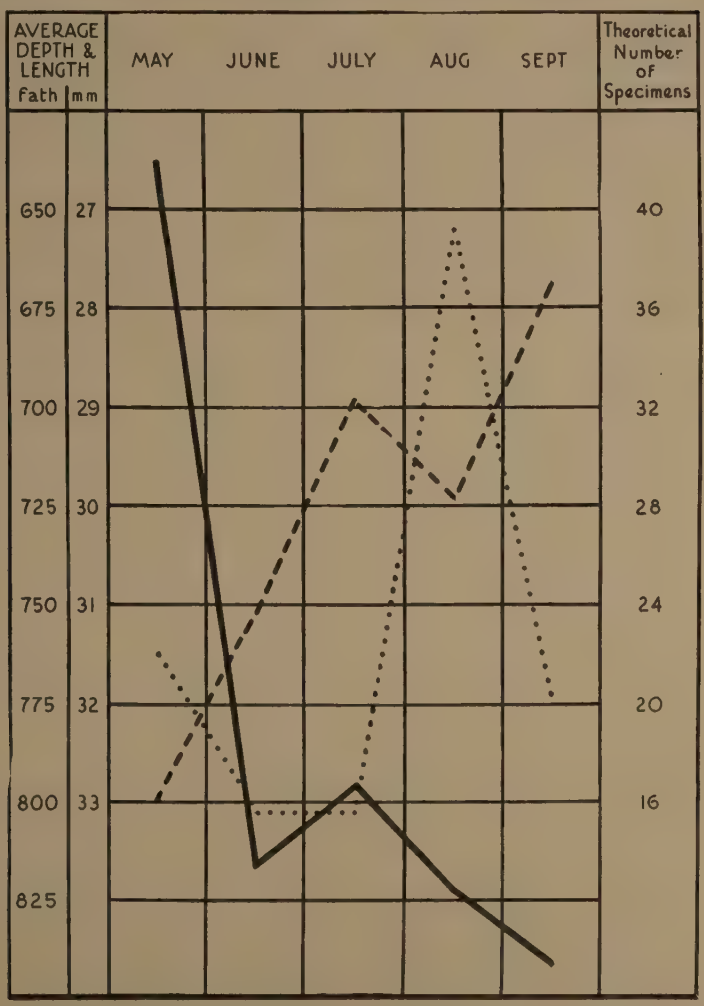


Fig. 46. *Bathylagus glacialis* Regan. The relation of month of capture to average length (dotted line), average depth (solid line) and theoretical numerical abundance[1] (broken line), all based on the total number of specimens taken by the Bermuda Oceanographic Expeditions.

Study Material

The following list gives the catalogue number, depth in fathoms, date of capture, length and growth stage of each specimen of *Bathy-*

[1] See fig. 45 and Introduction, p. 7.

lagus glacialis taken by the Bermuda Oceanographic Expeditiont. All were caught in the cylinder of water off the Bermuda coass described on p. 5. The abbreviations "P.-lar. Trans." and "Adol. Trans." stand for post-larval transition stage and adolescent transition stage, respectively.

No. 9,748; Net 64; 600 F.; May 4, 1929; 30 mm; Adolescent.
No. 10,261; Net 141; 600 F.; May 31, 1929; 26 mm; Adol. Trans.
No. 10,392; Net 162; 900 F.; June 6, 1929; 28 mm; Adol. Trans.
No. 10,717; Net 198; 1000 F.; June 20, 1929; 25 mm; Adolescent.
No. 10,891; Net 214; 800 F.; June 24, 1929; 46 mm; Adol. Trans.
No. 10,960; Net 220; 800 F.; June 25; 1929; 30 mm; Adolescent.
No. 10,963; Net 220; 800 F.; June 25, 1929; 27 mm; Post-larva.
No. 11,239; Net 252; 900 F.; July 4, 1929; 25 mm; P.-lar. Trans.
No. 11,237; Net 253; 1000 F.; July 4, 1929; 30 mm; Adolescent.
No. 11,508; Net 290; 1000 F.; July 11, 1929; 94 mm; Adult.
No. 11,635; Net 306; 600 F.; July 16, 1929; 25, 26 mm; Post-larva & P.-lar. Trans.
No. 11,860; Net 328; 800 F.; July 27, 1929; 26 mm; Adolescent.
No. 11,877; Net 330; 900 F.; July 27, 1929; 25, 26 mm; P.-lar. Trans.
No. 24,139; Net 351; 1000 F.; Aug. 8, 1929; 26 mm; Adolescent.
No. 12,179; Net 365; 1000 F.; Aug. 10, 1929; 29 mm; Adolescent.
No. 24,150; Net 371; 1000 F.; Aug. 14, 1929; 26 mm; P.-lar. Trans.
No. 12,433; Net 382; 900 F.; Aug. 16, 1929; 26, 26 mm; P.-lar. Trans. & Adolescent.
No. 12,498; Net 389; 1000 F.; Aug. 17, 1929; 30 mm; Adolescent.
No. 12,595; Net 395; 1000 F.; Aug. 23, 1929; 23 mm; P.-lar. Trans.
No. 12,982; Net 413; 900 F.; Sept. 3, 1929; 30 mm; Adolescent.
No. 13,189a; Net 435; 1000 F.; Sept. 6, 1929; 26 mm; P.-lar. Trans.
No. 13,228; Net 440; 900 F.; Sept. 7, 1929; 28 mm; Adolescent.
No. 13,239; Net 442; 1000 F.; Sept. 7, 1929; 27, 27, 27 mm; P.-lar. Trans.
No. 13,349; Net 449; 1000 F.; Sept. 9, 1929; 28, 28 mm; Adolescent.
No. 13,423; Net 460; 700 F.; Sept. 11, 1929; 30 mm; P.-lar. Trans.
No. 13,468; Net 466; 900 F.; Sept. 12, 1929; 28 mm; Adolescent.
No. 13,477; Net 468; 1000 F.; Sept. 12, 1929; 29 mm; Adolescent.
No. 13,584; Net 480; 700 F.; Sept. 20, 1929; 28 mm; Adolescent.
No. 13,585; Net 480; 700 F.; Sept. 20, 1929; 74 mm; Adult.
No. 13,637; Net 487; 800 F.; Sept. 21, 1929; 28 mm; P.-lar. Trans.
No. 13,782; Net 507; 700 F.; Sept. 25, 1929; 26 mm; Adolescent.

No. 14,803; Net 552; 600 F.; May 9, 1930; 27 mm; Adolescent.
No. 14,905; Net 565; 500 F.; May 12, 1930; 27, 27 mm; Adolescent.
No. 15,078; Net 590; 800 F.; May 17, 1930; 28 mm; Adolescent.
No. 15,149; Net 598; 800 F.; May 19, 1930; 55 mm; Adult.
No. 15,518; Net 647; 700 F.; May 29, 1930; 32 mm; Adol. Trans.
No. 15,696; Net 665; 700 F.; June 4, 1930; 44 mm; Adol. Trans.

No. 15,771; Net 682; 800 F.; June 7, 1930; 34, 40 mm; Adol. Trans.
No. 15,832; Net 686; 800 F.; June 9, 1930; 27 mm; Adolescent.
No. 16,036; Net 701; 800 F.; June 13, 1930; 30, 31 mm; Adolescent & Adol. Trans.
No. 15,991; Net 711; 800 F.; June 16, 1930; 34 mm; Adol. Trans.
No. 16,054; Net 713; 700 F.; June 17, 1930; 40, 40 mm; Adol. Trans.
No. 16,256; Net 721; 900 F.; June 25, 1930; 28 mm; P.-lar. Trans.
No. 16,261; Net 722; 900 F.; June 25, 1930; 27 mm; Adolescent.
No. 16,507; Net 748; 900 F.; June 30, 1930; 31 mm; Adolescent.
No. 16,927; Net 760; 700 F.; July 2, 1930; 54 mm; Adult.
No. 16,948; Net 761; 900 F.; July 2, 1930; 30 mm; Adolescent.
No. 16,953; Net 778; 700 F.; July 5, 1930; 31 mm; Adol. Trans.
No. 16,761; Net 788; 900 F.; July 7, 1930; 29, 29, 30 mm; Adolescent (2) & P.-lar. Trans.
No. 17,042; Net 801; 900 F.; July 15, 1930; 27 mm; Adolescent.
No. 17,190; Net 804; 500 F.; July 16, 1930; 28 mm; Post-larva.
No. 17,060; Net 806; 700 F.; July 16, 1930; 45 mm; Adol. Trans.
No. 17,204; Net 807; 800 F.; July 16, 1930; 29 mm; Adolescent.
No. 17,534; Net 825; 800 F.; Sept. 1, 1930; 60, 75 mm; Adults.
No. 17,634; Net 832; 900 F.; Sept. 2, 1930; 28 mm; Adolescent.
No. 17,791; Net 839; 700 F.; Sept. 3, 1930; 50 mm; Adol. Trans.
No. 17,958; Net 850; 800 F.; Sept. 5, 1930; 26 mm; P.-lar. Trans.
No. 18,030; Net 857; 900 F.; Sept. 6, 1930; 61 mm; Adult.
No. 18,101; Net 862; 800 F.; Sept. 8, 1930; 27 mm; Adolescent.
No. 18,115; Net 864; 1000 F.; Sept. 8, 1930; 26 mm; Adolescent.
No. 18,497; Net 883; 700 F.; Sept. 13, 1930; 25 mm; Adolescent.
No. 18,502; Net 884; 800 F.; Sept. 13, 1930; 26 mm; Adolescent.
No. 18,513; Net 886; 900 F.; Sept. 13, 1930; 26 mm; Adolescent.
No. 18,684; Net 896; 700 F.; Sept. 16, 1930; 28 mm; Adolescent.
No. 18,720; Net 905; 900 F.; Sept. 17, 1930; 25 mm; Adolescent.
No. 19,139; Net 925; 900 F.; Sept. 20, 1930; 24 mm; P.-lar. Trans.
No. 19,057; Net 930; 700 F.; Sept. 22, 1930; 27 mm; Adolescent.
No. 21,554; Net 1104; 700 F.; July 25, 1931; 27 mm; P.-lar. Trans.
No. 21,611; Net 1109; 600 F.; July 27, 1931; 26 mm; P.-lar. Trans.
No. 21,807; Net 1123; 700 F.; Aug. 3, 1931; 30 mm; Adolescent.
No. 21,904; Net 1133; 700 F.; Aug. 5. 1931; 28 mm; Adolescent.
No. 22,323; Net 1175; 600 F.; Aug. 14, 1931; 28 mm; Post-larva.
No. 22,330; Net 1177; 800 F.; Aug. 14, 1931; 30 mm; P.-lar. Trans.
No. 22,546; Net 1193; 500 F.; Aug. 18, 1931; 23 mm; Post-larva.
No. 22,530; Net 1194; 700 F.; Aug. 18, 1931; 29 mm; Post-larva.
No. 22,549; Net 1196; 800 F.; Aug. 18, 1931; 27, 28 mm; Adolescents.
No. 22,619; Net 1200; 600 F.; Aug. 19, 1931; 27 mm; Post-larva.
No. 22,909; Net 1245; 1000 F.; Aug. 31, 1931; 27 mm; Adolescent.
No. 22,977; Net 1251; 900 F.; Sept. 1, 1931; 28 mm; Adolescent.
No. 23,062; Net 1256; 700 F.; Sept. 3, 1931; 25 mm; Post-larva.
No. 23,119; Net 1263; 800 F.; Sept. 4, 1931; 28 mm; Adolescent.

No. 23,193; Net 1273; 800 F.; Sept. 7, 1931; 25 mm; P.-lar. Trans.
No. 23,318; Net 1292; 700 F.; Sept. 12, 1931; 26 mm; Adolescent.
No. 23,367; Net 1298; 800 F.; Sept. 14, 1931; 25 mm; Adolescent.
No. 23,674; Net 1328; 800 F.; Sept. 19, 1931; 27 mm; Adolescent.

The following specimens were cleared and stained in order to study the skeleton: No. 13,584 (KOH No. 944); No. 15,149 (KOH No. 861); No. 15,413 (KOH No. 635); No. 15,518 (KOH No. 1063); No. 16,507 (KOH No. 1151); No. 22,323 (KOH No. 1152).

Colored plates, outline drawings and photographs are filed under the following numbers: Colored plate B614; outline drawings B879, B880, B881, B882, B883; photograph B5346-L.

Synonymy and References

Bathylagus glacialis:

Regan, 1913 (part), p. 231, pl. IX, fig. 2. (4 specimens 80 to 100 mm; [one of the five types mentioned is *B. euryops* according to Norman, 1930, p. 275], 800 to 1400 [–0] fathoms; Antarctic Ocean. *Type Specimens.*)

Norman, 1930, p. 275, (*Discovery:* 6 specimens; 24 to 118 mm; 112 to 1350 (–0) M.; west of Cape Town; south of Tristan d'Acunha; northeast of Falkland I. *Nat'l. Mus. of Ireland:* 1 specimen; 135 mm; 695 to 720 fath.; Co. Kerry, S. W. Ireland).

Bathylagus antarcticus: (part).

Brauer, 1906, p. 13, fig. 2: (1 to 3 specimens, depending upon how many of the four mentioned are actually *B. antarcticus;* between 42 and 133.5 mm; 1500 to 2000 M.; Antarctic, south of Cape Town, Bouvet Island and Enderby Land).

Bibliography of References Used in the Present Paper

Barnard, K. H.
1925 A Monograph of the Marine Fishes of South Africa. Pt. I. Ann. South African Mus., Vol. 21.

Beebe, W.
1931 Bermuda Oceanographic Expeditions 1929–1930. Introduction. Zoologica, Vol. XIII, No. 1.
1931 Bermuda Oceanographic Expeditions 1929–1930. List of Nets and Data. Zoologica, Vol. XIII, No. 2.
1932 Bermuda Oceanographic Expeditions 1931. Individual Nets and Data. Zoologica, Vol. XIII, No. 3.

Brauer, A.
1906 Die Tiefsee Fische, I. Systematischer Teil. Wiss. Ergebnisse Deutsch. Tiefsee. Exp. Valdivia, Vol. 15, Lief 1.

Goode, G. B., and Bean, T. H.
1895 Oceanic Ichthyology. A treatise on the deep-sea and pelagic fishes of the world. Special Bull. U. S. Nat. Mus.

Jordan, D. S., and Evermann, B. W.
1896 The fishes of North and Middle America, Vol. I. Bull. U. S. Nat. Mus., 1896.

Norman, J. R.
1930 Oceanic Fishes and Flatfishes Collected in 1925–1927. Discovery Reports, Vol. II.

Parr, A. E.
1931 Deep-sea Fishes from off the Western Coast of North and Central America, with keys to the genera *Stomias, Diplophos, Melamphaes* and *Bregmaceros*, and a Revision of the *macropterus* group of the genus *Lampanyctus*. Bull. Bing. Ocean. Coll. Vol. II, Art. 4.

Regan, C. T.
1913 The Antarctic Fishes of the Scottish National Antarctic Expedition. Trans. Roy. Soc. Edinburgh, Vol. 49, Pt. 2, 1913.

Roule, L.
1916 Notice preliminaire sur quelques especes nouvelles or rares des poissons provenant des croisieres de S. S. S. le Prince de Monaco. Bull. Inst. Oceanogr. Monaco, No. 320.
1919 Poissons provenant des campagnes du yacht Princesse Alice et du yacht Hirondelle II. Res. Camp. Sci. Monaco, Fasc. 52.

Fig. 47. The Gleaming-tailed Sea Dragon. *Idiacanthus fasciola* Peters. Nearly adult females (length, about 130 mm.) and adult males. Originally intended to illustrate post-larvae and adults, before their life histories were understood. (From a painting by Else Bostelmann). (*Frontispiece*).

DEEP-SEA FISHES OF THE BERMUDA OCEANOGRAPHIC EXPEDITIONS

Family IDIACANTHIDAE*

By William Beebe

(Figs. 47–81 incl.)

Contents

INTRODUCTION

§ For detailed data of nets, locality, dates, etc., concerning the capture of the deep-sea fish treated in this monograph, refer to Zoologica, Vol. XIII, Nos. 1, 2 and 3, and for physical data, methods of measurement and definitions of growth stages see Zoologica, Vol. XVI, No. 1.

* Contribution, New York Zoological Society, Department of Tropical Research, No. 437.

§ All the material under consideration was taken in the course of thirteen hundred and fifty nets, drawn in one locality, an eight-mile circle, with its center at 32° 12′ North Latitude and 64° 36′ West Longitude, nine and a quarter miles south-southeast of Nonsuch Island, Bermuda. Vertically this is an imaginary cylinder, considered as extending from the surface to the bottom of the sea, an extreme range of fifteen hundred fathoms.

§ Exact depth levels of the nets are confirmed by the use of a reliable deep-sea pressure gauge (Bull. N. Y. Zool. Soc., Vol. XXXIII, No. 6, p. 244). As before, six metre-nets are used, strung at exact intervals along two miles of wire, drawn at an angle of thirty degrees, at the rate of two knots an hour.

§ In the preparation of this paper I have had the coöperation of my whole staff, Mr. Tee-Van in the original supervision of the capture of the deep-sea fish, Miss Hollister in the production of the cleared and stained preparations and the study and description of the tail fin and caudal region, and Miss Crane in the elaboration of the host of data. The drawings are the painstaking work of Mr. Edward Delano. Except where otherwise indicated in the captions, all were made from Bermuda specimens of *Idiacanthus fasciola*.

SUMMARY OF IMPORTANT POINTS

§ Rearrangement of Taxonomic Relationships: Most of the fish hitherto classified under the genus *Stylopthalmus* in the family Stylophthalmidae have proved to be the larvae of *Idiacanthus* of the family Idiacanthidae.

§ Stalked Eyes in Young. This character is not uncommon among invertebrates (shrimps, crabs, squids, gastropods) and is occasionally found in other groups of fish such as *Bathylagus*. In the present larvae it is carried to an extreme and is only analogous to the other stalk-eyed species, the origin of the cartilage being quite different. The character is a very specialized one, correlated with many primitive conditions of teeth and skeleton.

The change into sessile-eyed post-larvae is by absorption of the optic nerve, and the drawing down and coiling up of the cartilage stalk, followed by its inclusion into the anterior part of the eye-socket, its complete covering with epithelium and final absorption.

§ Sexual Dimorphism. The adult males are larvoid, having the following characteristics: one sixth as large as adult females, paler, post-larval in proportions of body, head, eye and snout; lacking teeth, pelvic fin and barbel; having long caudal fin; bones slightly or not at all ossified, of simple, larvoid shapes and relative positions; digestive apparatus useless and atrophied subsequent to post-larval stage; testicles precocious in development, commencing to swell during post-larval period; an apparently intromittent organ present, supported by the specialized first five rays of the anal fin. The only highly specialized, non-juvenile organ is the huge post-orbital light, the corresponding structure in the female being minute.

§ Specialized Feeding Adaptations of Adult Female. An unossified first vertebra permits considerable upward thrust of the upper jaw and entire skull, and long, elastic, ligamentous connections between the four ceratobranchials and epibranchials allow very great distension of the entire throat.

Early powers of prehension are insured by the precocious basibranchial fangs, which develop before the permanent jaw teeth.

§ Ecology. The breeding season of *Idiacanthus fasciola* is in the late summer. The larvae swim in schools at relatively shallow depths (ca. 100 fathoms), while subsequent stages are not trawled above 500 fathoms. One adult seen at 200 fathoms from Bathysphere.

Throughout development, local tissue activity is invariably indicated by the presence of an unusual amount of pigmentation, concentrated temporarily at the exact area.

§ Conjectures and Unsolved Problems. The adult males may be said to be parasitic, judged by their great numerical abundance, small size and larvoid characters. Their weak swimming powers and huge cheek lights would indicate that they are of the nature of passive reflectors, with the females doing the seeking, conditions reversing those existing between the sexes of fireflies.

The occlusion of the digestive trace necessitates some other form of nourishment, such as absorption of the liver, and narrows the period for the possible finding of a mate. The external generative organ, which I have tentatively called intromittent, is so closely attached to the anal fin by membrane, that actual insertion into the body of the female appears difficult, even disregarding the fact of the oviparity of the species. But I cannot account otherwise for the presence of such an elaborate and large-sized organ.

Suborder STOMIATOIDEA

Oceanic Isospondyls differing from the Clupeoids in the presence of photophores. Soft-rayed fishes with pectoral fins placed low, pelvics abdominal, mouth terminal, laterally cleft; maxillary entering gape and toothed; gill openings wide.

Family IDIACANTHIDAE

Idiacanthidae Gill (Goode and Bean 1895)
Stylophthalmidae (*partim*) Jordan 1923

Stomiatoid fishes closely related to the Melanostomiatidae, but differing in the following particulars: form very elongate; dorsal and anal fins long and low, the dorsal originating well in front of the middle of the body, the anal about three-fifths as long, both fins extending almost to caudal base; a pair of protruding lateral spines at the base of each dorsal and anal ray; unique luminous organs at base of caudal fin; sexual dimorphism extreme, the mature males being less than one-sixth as large as breeding females, and larvoid or post-larvoid in almost all characters except those of the reproductory system; larvae with stalked eyes. In common with the Melanostomiatids the Idiacanthids have the following characters: scales absent; teeth highly developed (but in female only); caudal fin very short (female only), forked, the ventral lobe the longer; postorbital organ present; barbel present (female only); serial photophores without lumen or duct, present as usual upon branchiostegal membrane and in a lateral and ventral series on each side; premaxillaries with pointed process anteriorly extending upwards and backwards over mesethmoids; one supplemental maxillary; parietals absent; gill-rakers absent; long, black caecal stomach present (female only) connected anteriorly by a short arm with the straight intestine; two pyloric caeca; membrane present connecting lower jaw with hyoid arch. As in some Melanostomiatids, pectorals absent, except in young, and gill arches toothless. No adipose fin.

Oceanic and deep-sea fish of cosmopolitan distribution.

Only one genus is known, containing about five species.

The Bermuda Oceanographic Expeditions captured 129 specimens, all belonging to a single species, *Idiacanthus fasciola*, including specimens hitherto referred to the family Stylopthalmidae. In the order of abundance of individuals in the nets this fish ranks seventh

among the 12 families of deep-sea Isospondyls represented in the collection and seventh also among the total of 41 Isospondylous genera. Hence this family is numerically comparable to both the Alepocephalidae and Bathylagidae (see Zoologica, Vol. XVI, Nos. 2 and 3), but far less abundant than most of the remaining families of Stomiatoid fishes, notably the Gonostomids and Sternoptychids.

Genus **Idiacanthus** Peters 1876

GENERIC CHARACTERS. With the characteristics of the family. Cleft of mouth slightly curved; mandible projecting; premaxillary and mandible with a single series of depressible, unequal, bicuspid teeth, some of which are elongate fangs; maxillary with one or two series of erect and a single series of minute oblique teeth; a single series of teeth on vomer, several teeth on each palatine and two pairs on basibranchials; pelvics present in female only, six-rayed, situated in advance of middle of body; dorsal 54 to 74, extending over posterior two-thirds of body (i. e., in female nearly to or in advance of pelvics); anal 34 to 49, shorter than dorsal; dorsal and anal rays wide-set except posteriorly; postorbital organ minute in female, enormous in male; barbel present in female only, 1.3 to 2.5 times length of head, and of almost identical structure in all species: stem black; bulb half as long as stem, only slightly swollen, tapering distally to a point, lightly pigmented; proximally the bulb has a pair of lateral, oblique, transparent expansions; distal to these are two similar flanges, one anterior and the other posterior; near the base of the bulb anteriorly is a short, tapering filament with a pair of small translucent lobes proximally and several minute luminous bodies distally, the first being largest.

In the structure of the head, teeth and skull *Idiacanthus* closely resembles the genus *Melanostomias*, while the curved lower jaw is similar to that of *Photonectes*. However, until it is proved that striking examples of sexual dimorphism and highly specialized larval forms, such as are found in *Idiacanthus*, occur also among the Melanostomiatidae the maintenance of a separate family is amply justified.

GEOGRAPHICAL DISTRIBUTION: The accompanying map (Fig. 48) shows the general localities where specimens of *Idiacanthus* have been taken. Five species are probably valid. *I. fasciola* is known from the North Atlantic, Indian, and far western Pacific Oceans—a wide range, but limited to the temperate and tropical parts of the

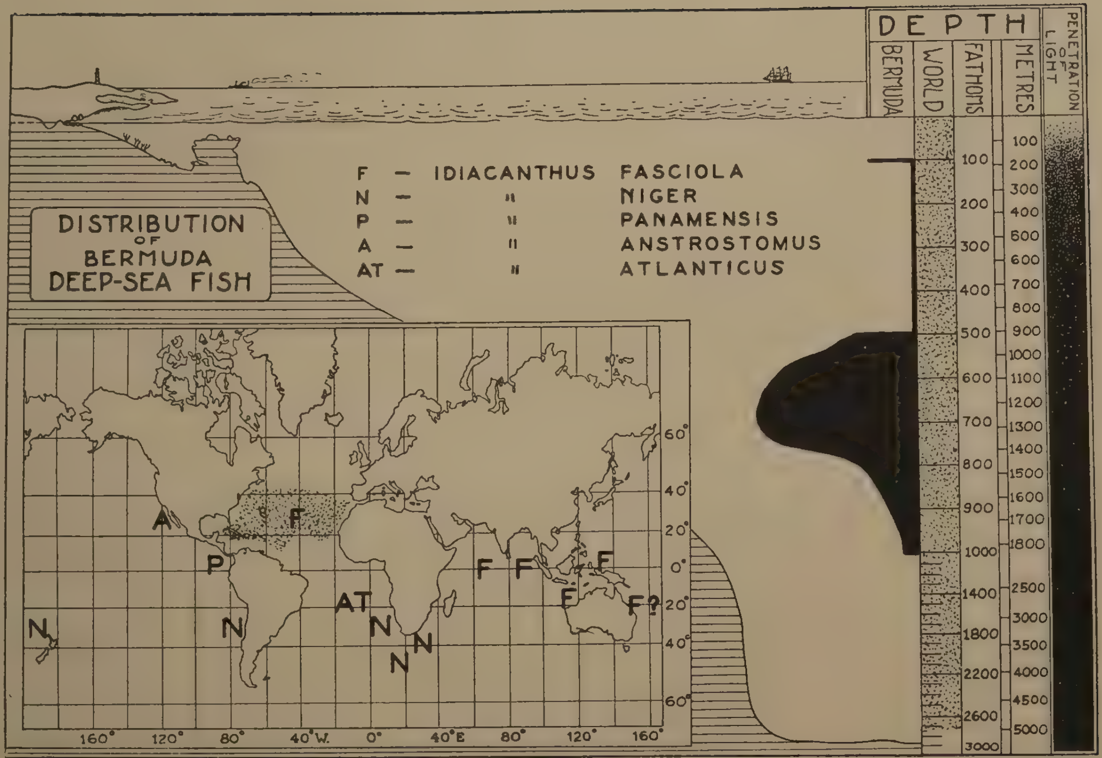


Fig. 48. The geographical and vertical distribution of the genus *Idiacanthus*. The relative number of specimens of *I. fasciola* taken at different depths by the Bermuda Oceanographic Expeditions is shown diagrammatically at the left of the column which gives the vertical range of the genus.

northern hemisphere and the warmer portions of the southern. *I. niger*, distinguished by the more anterior position of the pelvics, is confined entirely to the temperate parts of the southern hemisphere. *I. panamensis*, a species notable for the high development of its luminous tissue, has been taken only in the Gulf of Panama. The two remaining species, *I. anstrostomus* and *I. atlanticus*, from off California and from the southeastern Atlantic, respectively, are known only from single specimens. Of special interest is the dubius specimen taken off eastern Australia, as this locality is exactly between the ranges of *I. fasciola* and *I. niger*. This Australian fish was first described as *I. aurora* by Waite in 1916, subsequently (Regan, 1916) tentatively synonymized with *I. niger* and most recently (Regan and Trewavas 1930) with *I. fasciola*.

Brauer's records of *Stylophthalmus paradoxus* have been omitted from the map because, although *Idiacanthus* is undoubtedly included among his specimens, other forms are also present, and in his remarks on their geographical distribution he does not list separately the individuals taken in each locality. An inspection of the drawings and descriptions of stylophthalmine fish recorded by various other authors[1] shows that not one of their specimens can be *Idiacanthus*. Some of these have been already reidentified as the young of Myctophids (Sanzo, 1915, p. 133; 1920, p. 721), of *Eustomias* (Regan and Trewavas 1930, p. 73), and of *Bathylagus* (Taaning 1931, p. 272). Roule and Angel (1930, p. 55 ff.) suggested that the very dissimilar, stylophthalmine forms in their collection were all juvenile and even abnormal Myctophids; their illustrations show, however, that young Argentinids are undoubtedly represented in the series and probably Stomiatoids as well, and there seems to be no evidence that any of these specimens are monsters. Reëxamination of the Hudson Gorge specimens referred to *Stylophthalmus paradoxus* (Beebe 1929, p. 9) has resulted in the identification of the larger as an early postlarval *Idiacanthus fasciola*. The systematic position of the smaller is still uncertain.

DEVELOPMENT: The figures given under the heading "Postlarval examples of *Idiacanthus*" by Regan and Trewavas (1930, pp. 132–133) include both adolescent females and adolescent and adult males. The unequal development of the cheek light in the two

[1] Lo Bianco 1903, p. 167; Ehrenbaum 1905–1909, p. 360; Holt and Byrne 1907, p. 189; Mazzarelli 1912; Murray and Hjort 1912, p. 86, 746; Weber 1913, p. 16; Regan 1916, pp. 136–137; Roule and Angel 1930, pp. 50–56.

sexes has led to a number of hypotheses such as that of Regan: "we infer that the early post-larval fish live not far below the surface, that a little later they migrate to greater depths, 1000 metres or more below the surface, that the temporary increase in size of the eye and of the postocular luminous organ is an adaptation to a life in the depths. . . . The young fish may perhaps ascend to lesser depths."

It is now apparent also that the "nasal tubes" shown in the drawings of *I. panamensis* (*loc. cit.*, fig. 129A, D) are the damaged remains of larval eye-stalks of a young male and a young female respectively; as in a number of the Bermuda specimens, the stalks were broken off or their ocular ends torn loose before the normal process of close coiling and epithelial covering of the post-narial, preocular socket could be completed. The similarity of these immature and male specimens of *I. panamensis* to the corresponding forms of *I. fasciola* establishes without question the general occurrence of stalk-eyed young and larvoid males throughout the genus.

The small specimen described by Weber (1913, p. 15) is also a male.

A detailed account of the development of these fish resulting from the study of the Bermuda specimens commences on page 157.

Idiacanthus fasciola Peters 1876

Specimens taken by the Bermuda Oceanographic Expeditions

129 specimens; April to October, 1929 to 1931; 100 to 1000 fathoms; from a cylinder of water 8 miles in diameter (5 to 13 miles south of Nonsuch Island, Bermuda), the center of which is at 32° 12′ N. Lat., 64° 36′ W. Long.; Standard lengths from 16 to 270 mm.

Specimens Previously Recorded

About 350 specimens; surface to 2750 fathoms; Atlantic, Pacific and Indian Oceans; 10? to 320 mm (possibly to 408 mm).

Adult Specific Characters

Idiacanthus fasciola is distinguished from the other four probably valid species in the genus by the following combination of characters, found only in the adult female: pelvics below first to

eighth dorsal ray, their distance from anal more than one-half their distance from snout; 15 to 18 photophores from pelvic to anal origin. *Color:* (from fresh specimens). Skin: female, brownish black; male, dark brown. Postorbital: female, pinkish silver; male creamy white. Barbel: (female only) stem dark brown, bulb pigmented with translucent flanges and a pale yellow anterior filament. Serial photophores: female, scarlet to purple, the ventral series gold-capped; male, violet. Caudal organs: female, golden yellow; male, creamy yellow. *Proportions:* Depth in length: female, 19 to 27; male, 18 to 22; head in length: female, 15 to 18; male 8.5 to 10.5; eye in head: female, 5 to 7; male, 3 to 4; origin of anal to caudal base in length of fish: female, 2.5 to 3; in male, 3.6 to 4.1; postorbital in head: female, 40 to 50; male 2 to 3; barbel: (female only) 2 to 2.5 times length of head, the anterior filament with a prominent swelling. *Finray Counts:* Pectoral 0; pelvic (female only) 6; dorsal 54 to 74; anal 38 to 49. *Serial Photophores:* Female: lateral series, O–V 21 to 25, V–A 30 to 36; ventral series, I–V 33 to 36, V–A 30 to 36 (15 to 18 to anal origin); A–C 14 to 18. Male: lateral series, O–A 48 to 55; ventral series, I–A 58 to 65 (54 to 59 before anal origin), A–C 16 to 20. *Miscellaneous Luminous Organs:* Female: Bases of teeth filled with luminous matter; a very small, white, luminous patch below postorbital organ; three longitudinal series of similar patches along body, dying out caudally; a moderate amount of granular luminous material on unpaired fins; a small mass of yellow tissue on the dorsal surface of the caudal peduncle extending out onto the raylets; a similar, but larger body, with a small one distal to it, in the ventral lobe of the caudal fin; first pelvic ray with small, round photophore-like patches. Male: Luminous matter within jaw bones; abundant luminous granular material on unpaired fins; caudal organs similar to female's, but relatively smaller, paler, the more distal organ in the ventral caudal lobe rudimentary or absent.

Development

The 129 specimens of *Idiacanthus fasciola* in the Bermuda collection represent all stages of development from young larvae of 16 mm to mature females and males measuring up to 270 mm and 44 mm in length respectively. The following table shows the relation of these growth stages to standard length, sex and numerical abundance:

	Sex Unknown	Females	Males	Total
Larvae: 16–28 mm	13	—	—	13
Post-larvae: 36–50 mm	—	9	10	19
Adolescents (Females: 43–161 mm; Males: 28–40 mm)	—	20	17	37
Adults (Females: 190–270 mm; Males: 32–44 mm)	—	4	56	60
Total	13	33	83	129

In a word, the immature specimens are almost evenly divided between the sexes, but the adult males are 14 times more numerous than the adult females and less than one-sixth as long. When all of the specimens in which sex can be determined are counted, the ratio of males to females is 2½ to 1. Adult males form over two-fifths of the entire collection.

In development *Idiacanthus* is typically Stomiatoid except for the stalked eyes of the larvae and the degenerate, post-larvoid form of the males. The latter throughout life lack teeth, pelvic fins and barbel, but develop enormous postorbital light organs and are sexually highly precocious, to mention only the most obvious of their peculiarities. Therefore the criteria ordinarily used in referring young Stomiatoids to particular growth stages, although perfectly applicable to the female, are of little value in the case of the male. Nevertheless there is a complete series composed of several well defined stages which are as logically the post-larval, adolescent and transitional forms of the male as are corresponding degrees of development in the female. As far as appearances are concerned (omitting sexual characters which make even adult males resemble post-larvae in many respects), the growth stages of the two sexes are correlated as follows:

Female		Male
Larvae (sex indeterminable)		
Post-larvae	=	Post-larvae
Transitional Post-larvae	=	Adolescents
Adolescents	=	Transitional Adolescents
—		Adults
Transitional Adolescents		—
Adults		—

In the following summary of the characteristics of the growth stages, both the Stomiatoid affinities of the fish and the specializations mentioned above are apparent: The larva is characterized by a pendulous gut with protruding end, a slender body, large head, large eyes at the end of long stalks, long flat snout, small mouth, larval denticles, rudimentary fins with strong pectoral pad, and a lack both of general body pigment and of light organs; this is a period of growth.

In the post-larva the eye-stalks are gradually absorbed while fins and light organs are forming, the head, eye and snout reduced and the gape enlarged. Sex is now determinable as the barbel and pelvics of the female are distinguishable while the postorbital organs of the male are already enlarged and the gonads slightly swollen. There is however, no appreciable difference in size between post-larvae of corresponding stages but different sexes. These young fish are long compared with the majority of Stomiatoids, unmetamorphosed *Idiacanthus* post-larvae reaching a length of 50 mm. There seems to be little or no growth during this stage. Shrinkage, accompanied by increased depth, takes place in both sexes during the later post-larval and early adolescent periods, slight in the case of the female (7 mm or less), great in that of the male (possibly up to 20 mm).

During adolescence in both sexes all traces of eye-stalks and pectoral fins vanish, pigment appears and the gape increases enormously (though to a greater extent in the female than in the male), but here the parallelism ceases. The female, exactly as in related forms, slowly develops teeth, barbel, bone and stomach; the skin blackens; head, eye and snout become further reduced and the postorbital organ minute; and a long transitional adolescence of actual growth is passed through before the gonads become at all enlarged and sexual maturity attained. In contrast, the male passes quickly through adolescence to adult-hood, always a stage ahead of the female, having few changes to make in its organization. The postorbital organ becomes enormous, the gonads swell to great proportions, and an external copulatory organ is formed, supported by the specialized first rays of the anal fin—these are the only positive developments made subsequent to metamorphosis. The other characters are static or degenerate, as the skin remains relatively light, the head and eye large, the snout long, the mouth edentulous, pelvic fins and barbel absent and the skeleton almost or entirely

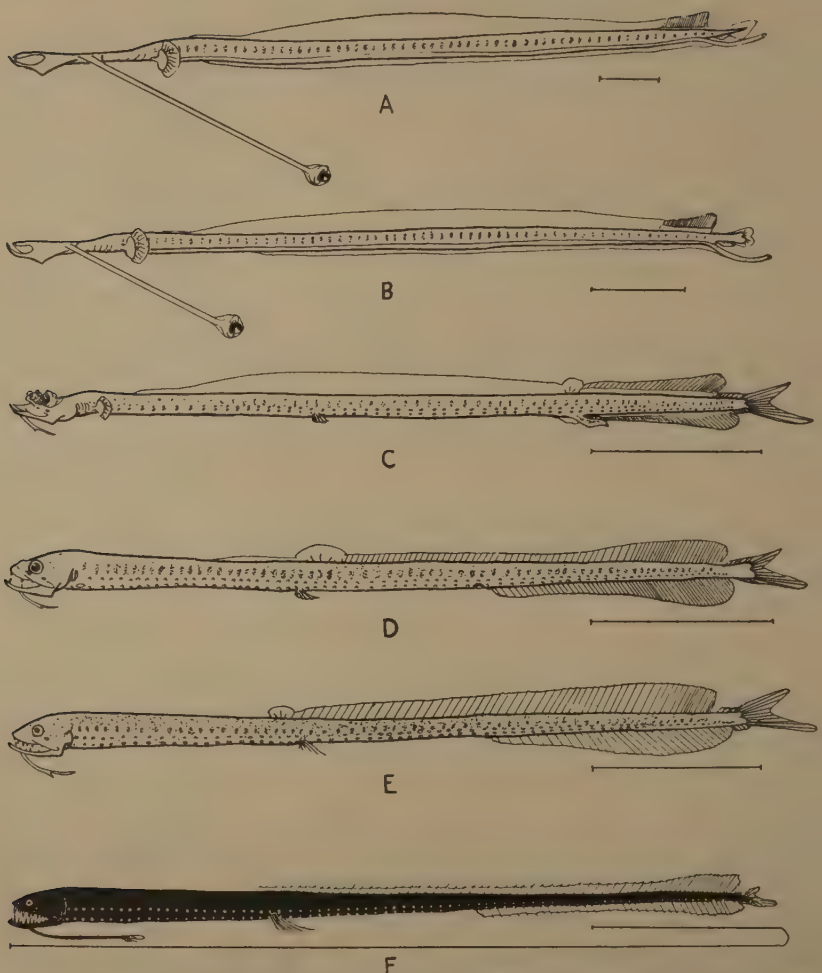


Fig. 49. Growth stages of female: A and B, sexually indeterminable larvae, 16 mm. and 25 mm., respectively; C, female post-larva, 45 mm; D, female transitional post-larva, 48 mm; E, female adolescent, 45 mm; F, female adult, 267 mm. The relative size of the specimens is indicated by the straight lines.

cartilaginous, while the digestive system atrophies and becomes completely useless. As is to be expected, there is no increase in length.

Detailed descriptions of each growth stage are given below.

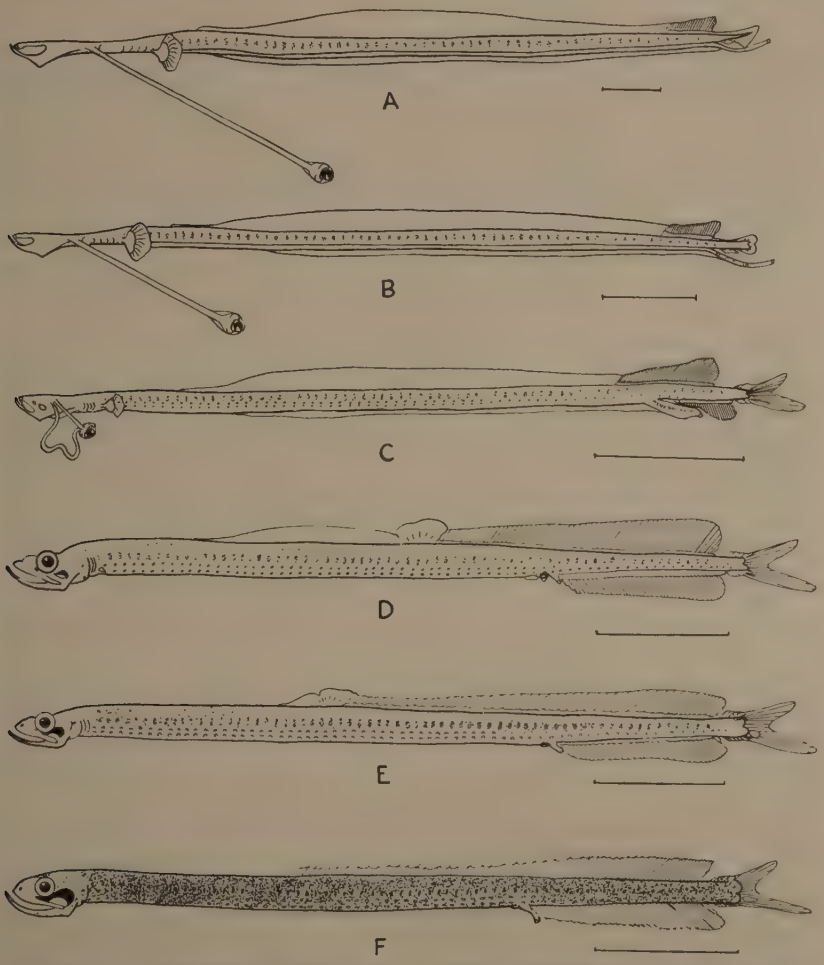


Fig. 50. Growth stages of male: A and B, sexually indeterminable larvae, 16 mm and 25 mm, respectively; C, male post-larva, 40 mm; D, male adolescent, 35 mm; E, male transitional adolescent, 35 mm; F, male adult, 38 mm. The relative size of the specimens is indicated by the straight lines. For ease in comparison the larvae of Fig. 49 (A and B) are reproduced in this figure also.

EGGS: The single breeding female (standard length 267 mm) of the collection contained a total of about 14,000 fully developed eggs. The transparent, minutely dimpled, egg membranes measure between .5 and .6 mm in diameter, the yolks between .4 and .45 mm.

In the majority of eggs one large and from two to eight small oil globules are clearly visible. Undeveloped, very minute eggs are present in small numbers between the fully developed ones, but there are no intermediate sizes. The eggs in the anterior part of each ovary are full size, but much paler in color (white, whereas the rest have deep yellow yolks in preservative) and almost opaque, with no distinction between yolk and outer membrane and no sign of oil globules.

In the other three mature females (190 to 270 mm) the eggs are graduated in size, instead of being of two sizes only, and the largest are only one-third to one-half as big as in the breeding

Fig. 51. Stalk-eyed larva and post-larva. (From a painting by Else Bostelmann).

Fig. 52. Stalk-eyed larva photographed beside young deep-sea shrimp (*Sergestes* sp.), showing the presence of stalked eyes in wholly unrelated phyla.

specimens (.2 to .3 mm in diameter). Similarly, the ovaries are only one-fourth to one-third as broad and are very flat.

Among the transitional adolescent females (48 to 161 mm) the largest eggs of each measure from less than .01 mm to .06 mm in diameter, while the ovaries are slender ribbons, .6 mm broad in the longest specimen, mere strings in the small examples, and all divided from their mates on the opposite side of the dorsal mid-line by a considerable space. In all except the largest specimens—that is, in all fish 125 mm long or less—the eggs are individually very feebly developed, translucent and jelly-like.

Eggs of adolescent fish are individually indiscernible.

LARVA: The 13 larvae, measuring from 16 to 28 mm in standard length, differ little from one another in appearance and proportions. The one great difference is in the size of the liver, which is relatively about three times as large in the largest specimens as in the smallest. On the other hand, the eye-stalks are almost as long in actual measurement in the shortest larvae as in the longest, so that in this character there is a relative reduction in stalk length, although throughout the stage the eye-balls remain firmly fixed at the extreme tips of the stalks. I agree with Taaning's suggestion (1932, p. 272) that Brauer's youngest, short-stalked specimens were probably young *Bathylagus*, as very similar Bermuda specimens proved to belong to this genus.

Larval Trawling Data: The description given below is verified and supplemented as usual by study of all of the larvae in the collection, both uncleared and cleared, but the actual measurements are taken from the following specimen: Department of Tropical Research No. 23,545a; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1308; September 16, 1931; 7 miles south of Nonsuch Island, Bermuda; 100 fathoms; Standard length 16 mm.

Larval Measurements and Counts: Standard length 16 mm; depth .43 (in length 37.2); head 3 (in length 5.3); eye diameter, horizontal, .2 (in head 15, in length 80); eye diameter, vertical, .54 (in head 5.6); base of stalk to tip of lens 6 (in length 2.7); snout 1.4 (in head 2.1, in length 11.4); maxillary .8 (in head 3.7, in length 20) dorsal origin to caudal base 1.9 (in length 8.4); dorsal rays 24; anal ray bases 10; projecting, terminal portion of gut 1.4.

Larval External Characters: (Figs. 49A, B; 50A, B; 51; 52; 53A,

A′). There are about 64 mid-lateral blotches from the gill-slit almost to the caudal base, one in the middle of each myomere. In addition, 6 much smaller spots are found along the mid-line of the isthmus. The rest of the larva is entirely unpigmented and almost transparent, especially in the cephalic region.

In general form this young fish is even more elongate than the adult, and of a nearly constant calibre as far back as the dorsal origin. From here the body tapers abruptly to its pointed tip, the caudal peduncle being exceedingly short. The head is large, somewhat under a fifth of the standard length, and much flattened. The snout is broad, fully half the length of the head, and perfectly horizontal. The jaws are typical of Stomiatoid larvae, the premaxillary a minute sliver of cartilage, the maxillary reaching halfway to the base of the eye-stalk, at about the same vertical as the prominent mandibular angle. The nostrils are located far forward, close behind the premaxillary but well separated from each other by the mesethmoid cartilage.

The structure of the eyes and stalks agrees well with Brauer's description of the long-stalked stage of *Stylophthalmus* (1908, p. 179 ff.). The principal elements of the stalk are cartilaginous rod and the optic nerve. The first is an outgrowth of the cartilage of both the future frontal bone and of the parasphenoid, and runs the full length of the stalk on its anterior side, disappearing into the outer membranes of the eye-ball. The second element, the optic nerve, arises from the forebrain and runs along the posterior side of the stalk. Both cartilage and nerve, as well as the various small muscles, tactile nerves and blood vessels, are enclosed in a common, transparent sheath which extends completely around the eye itself, protecting the lens just as in older fish. The eye-ball is located at the extreme tip of the stalk, the major portion of the round lens projecting beyond the shallow, elliptical, thick-lipped saucer of the eye-ball proper.

Both jaws contain fine denticles of a typically larval Stomiatoid character: these are directed straight outwards in the premaxillary and mandible, and downwards in the maxillary. The numbers are as follows: premaxillary 7; maxillary 13, increasing slightly in size posteriorly and with larger spaces between them; mandible 7, similarly increasing in size, but present in the anterior part of that jaw only.

The gill slits are wide open, with no trace of operculum.

The pectoral fins are relatively very large, the great fleshy pads resting on sturdy columns and fringed deeply with raylets. The following measurements were taken: maximum length of fin, from origin of base to tip of raylets, .7 mm; maximum expanse of base .43 mm. There is no trace of pelvics. The dorsal is far back, occupying only the posterior six per cent of the body, the rays short, close-set, with prominent bases. The anal is rudimentary, located behind the end of the dorsal, with no true rays apparent, although the bases of about ten are distinguishable. These arise toward the middle of the low finfold which runs from the exit of the intestine to the caudal fin. The latter has no true rays, is pointed, and extends little beyond the urostyle, with the ventral portion more developed than the dorsal.

There are both dorsal and ventral finfolds along the profiles from nape to caudal. These are deepest dorsally behind mid-body where the fold considerably exceeds the maximum body depth. The entire ventral finfold, however, is very shallow.

Larval Osteology: The skeleton is completely unossified. In the fresh and preserved specimens the head is so transparent that details of the cartilaginous elements can be studied more easily than in artificially cleared examples.

Larval skull: (Fig. 58). The top of the skull forms roughly an elongate rectangle with the eye-stalks arising about half-way between the snout and the posterior end of the supraoccipital. The cartilaginous areas, while very distinct, are exceedingly homogeneous as regards division into future elements. At the anterior end of the upper jaw the mesethmoids, in some individuals, are set off by extremely faint lines of demarcation. Behind them the frontals join down the center but show in that region a narrow, clear area between very low ridges. Posteriorly, in older larvae, they can be traced over about half of the outer lobe of the brain. The width of the skull from eye-stalk forward is doubled by rigid lateral membrane. The supraoccipital is very large, covering the entire brain and midway of its length expanding into large, rounded, lateral wings. Outside the widest of these expansions we find the rather indefinite sphenotic characterized even at this stage by a lateral projection. Posterior to this is the pterotic, which curves decidedly inward toward the mid-line. The elongate, oval epiotic follows, projecting

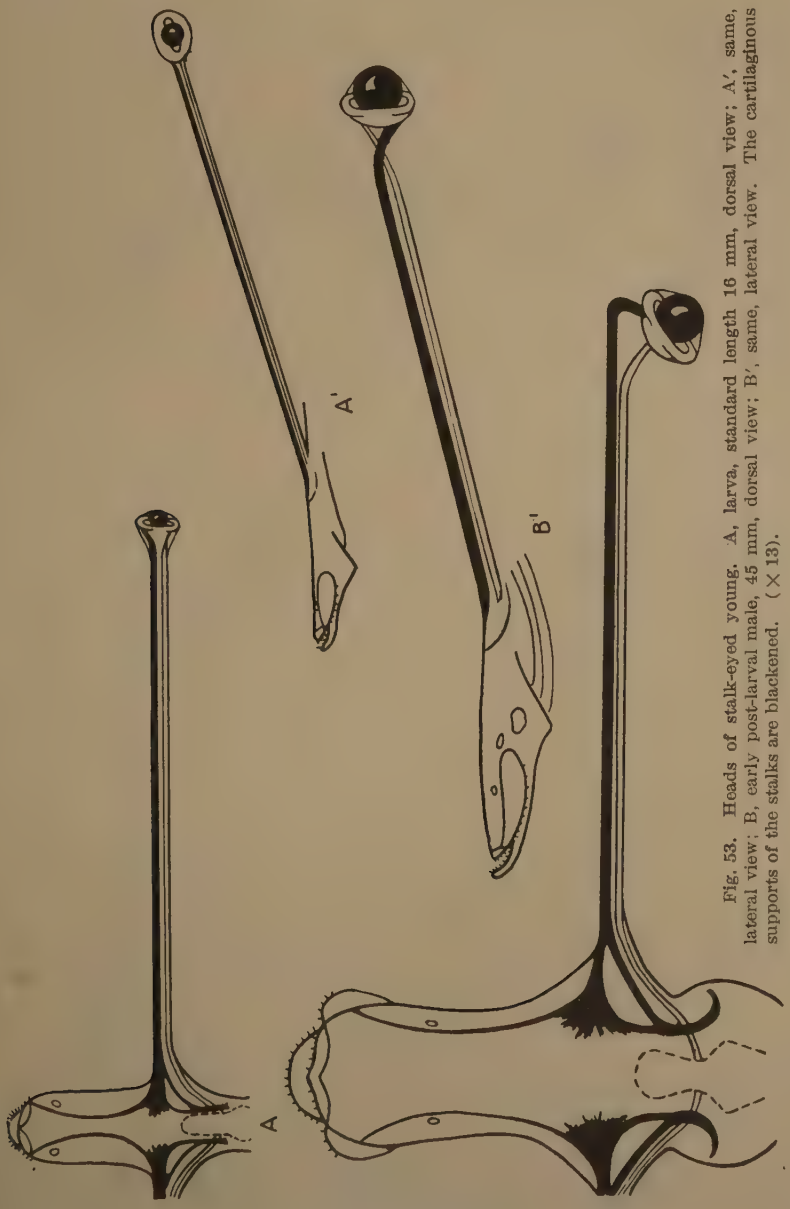


Fig. 53. Heads of stalk-eyed young. A, larva, standard length 16 mm, dorsal view; A', same, lateral view; B, early post-larval male, 45 mm, dorsal view; B', same, lateral view. The cartilaginous supports of the stalks are blackened. (× 13).

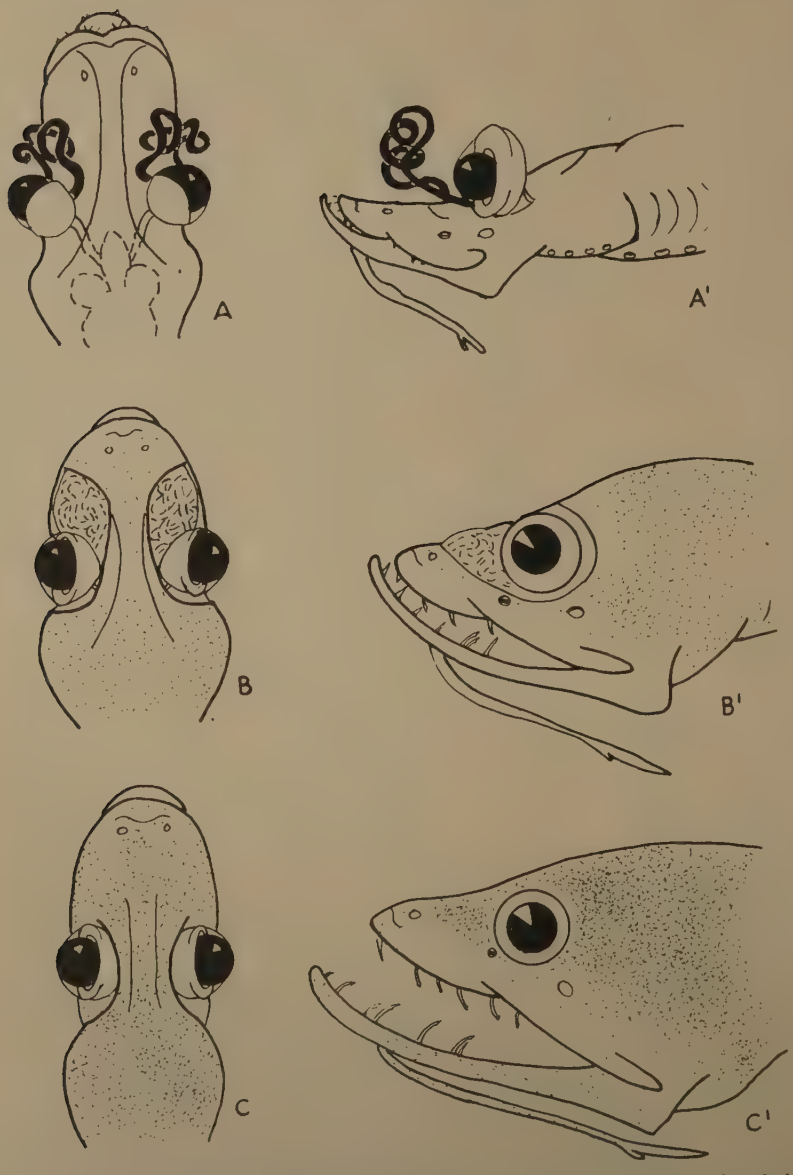


Fig. 54. Heads of young females. A, post-larva, standard length 45 mm, dorsal view; A′, same, lateral view; B, transitional post-larva, 48 mm, dorsal view; B′, same, lateral view; C, adolescent, 43 mm, dorsal view; C′, same, lateral view. (× 13).

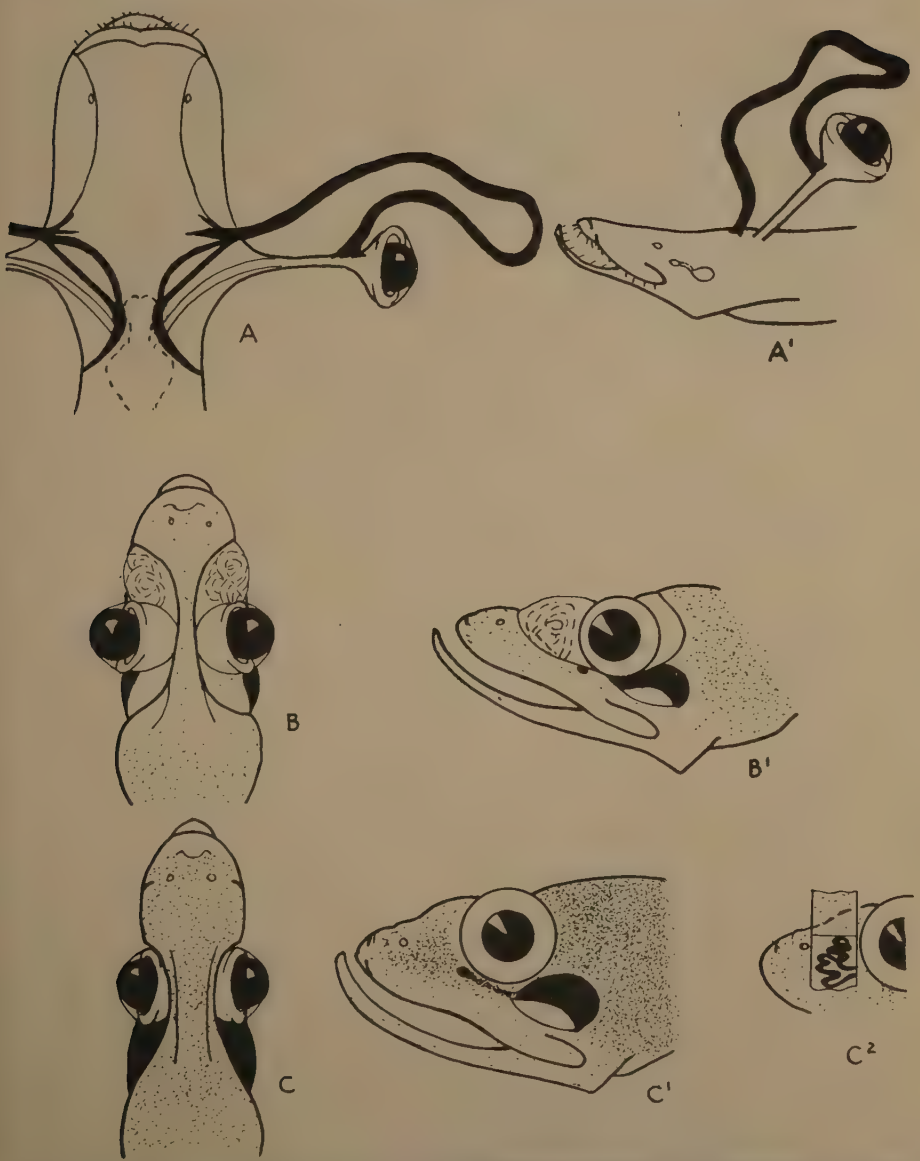


Fig 55. Heads of young males. A, post-larva, standard length 40 mm, dorsal view; A′, same, lateral view; B, adolescent, 35 mm, dorsal view; B′, same, lateral view; C, transitional adolescent, 35 mm, dorsal view; C′, same, lateral view; C², same, with flap of skin lifted to expose eye-stalk coiled behind nostril. (× 13).

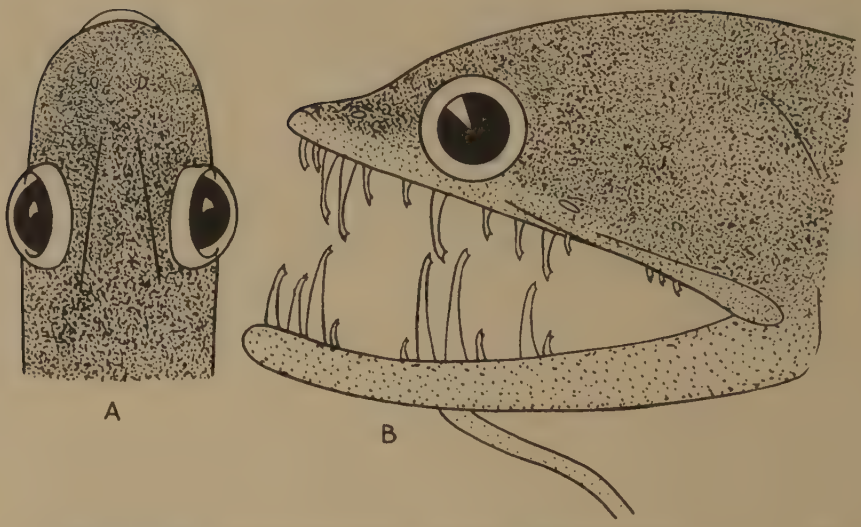


Fig. 56. Head of female transitional adolescent, standard length 75 mm. A, dorsal view; B, lateral view. (× 13).

backwards well beyond the supraoccipital. In the roof of the mouth the parasphenoid appears to be represented by a low median ridge which posteriorly expands and forms the base of the brain.

At about the middle of the length of the skull the frontals above and the parasphenoid below unite into large, solid, lateral projections which support the main rods of the long eye-stalks already described. The elements of the projections are flattened along their extended base, but almost immediately contract at each side into a cylindrical rod. Just beyond the limits of the skull the actual cartilage of the rod gives place to a striated tissue, apparently muscular, but after a very short distance cartilage reappears and continues unbroken throughout the eye-stalk. This short, altered area doubtless affords the requisite pliability, allowing the strong, basal muscles to draw the eye-stalks forward and back. A second, smaller, cartilaginous rod arises near the meeting of the parasphenoid and the anterior end of the supraoccipital and enters the stalk just posterior to the larger anterior rod.

Larval palato-pterygoid arcade: (Fig. 59). Even in detailed delineation the lateral view of the head presents an appearance of diagrammatic simplicity, the bones of the head and the branchial

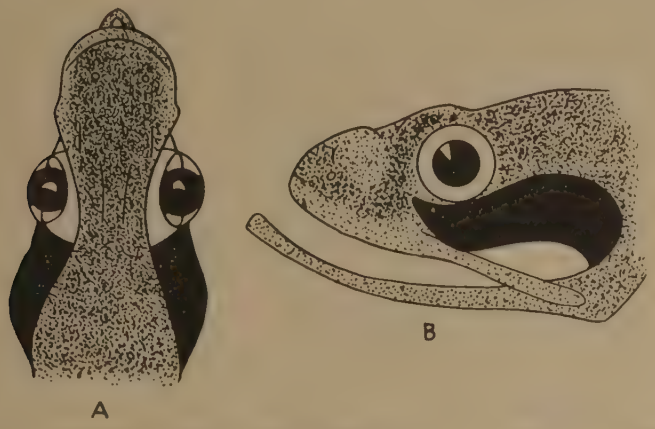


Fig. 57. Head of adult male, standard length 38 mm. A, dorsal view; B, lateral view. (× 13).

arches being almost all of simple, rod-like, elongate character. The hyomandibular shows at its upper end a knob-like articulation with the pterotic. From here it extends forward, narrowing rapidly while at the same time its superior width is maintained by the appearance and increasing width of the quadrate. Directly above the quadrate and parallel with it is the long, narrow pterygoid. Its posterior end disappears in the surrounding tissue while anteriorly it is loosely connected with the palatine.

Larval jaw apparatus: (Figs. 59, 60). The primary upper jaw consists of a short premaxillary lacking the dorsal prolongation found in the adult and attached to the extremely long, straight maxillary which widens gradually toward its proximal articulation. The supramaxillary is distinct and contained within the even curve of its outline. The lower jaw shows a slight upward curve in its distal third and widens considerably at its attachment to the quadrate, showing a deep bay for articulation with the head of the latter bone.

Larval opercular bones: (Fig. 59). The only hint of the opercular apparatus is a slender, needle-like, cartilaginous bar extending close beneath the hyomandibular and dying out about half way down the quadrate.

Larval hyoid apparatus: (Fig. 59). The glossohyal is relatively large, broadly shield-shaped as seen from above, deeply incised on its anterior profile and about one-third as long as the entire lower jaw.

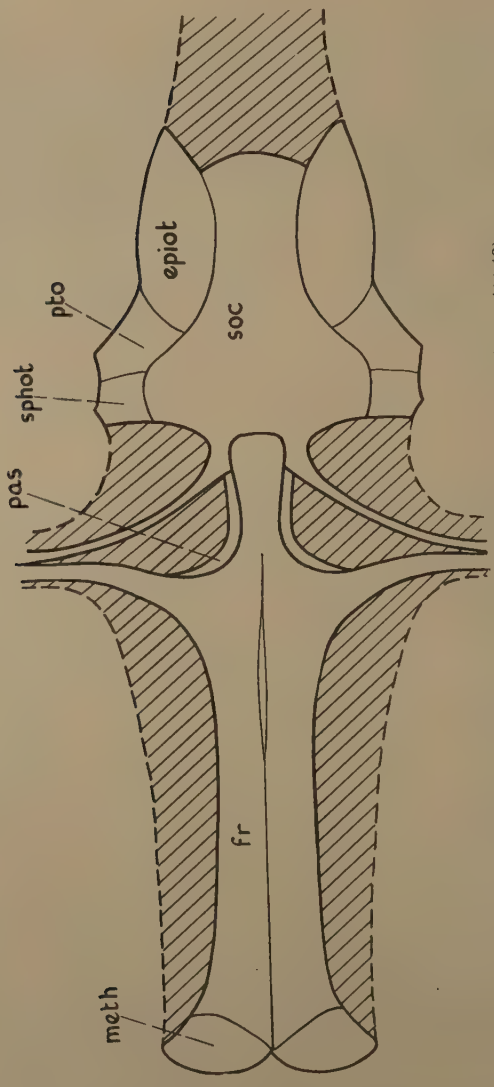


Fig. 58. Cartilaginous elements of larval skull, dorsal view. (× 40).

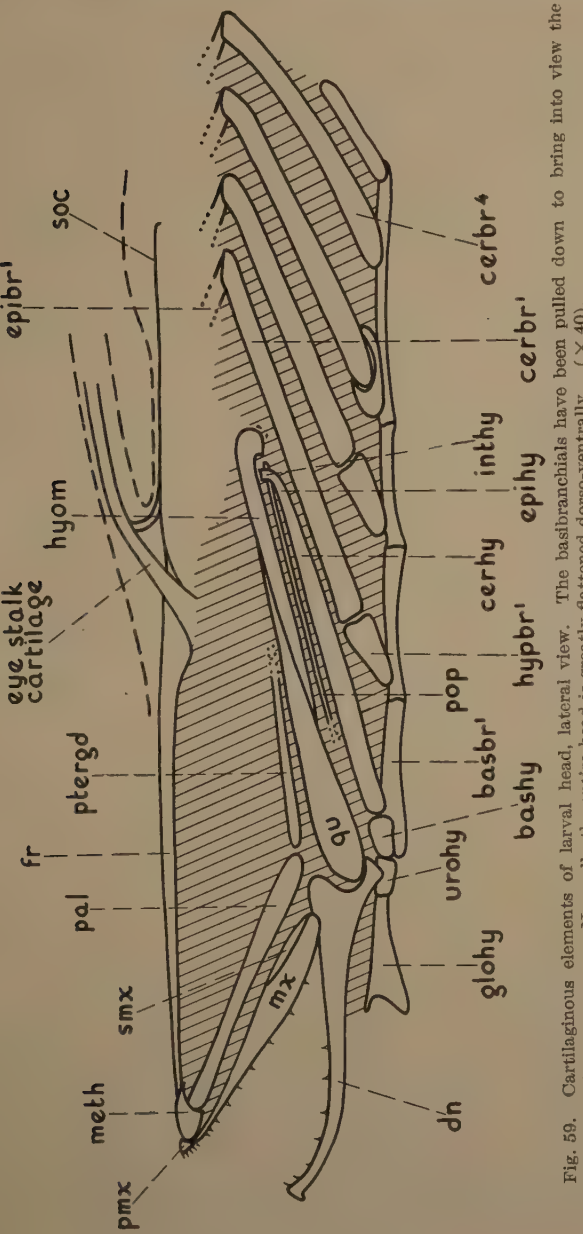


Fig. 59. Cartilaginous elements of larval head, lateral view. The basibranchials have been pulled down to bring into view the hyoid and branchial apparatus. Normally the entire head is greatly flattened dorso-ventrally. (× 40).

Directly behind it is a small, roughly square urohyal. The basihyal is about the same size and shape as the urohyal, and is succeeded by a long, stout ceratohyal longer than the entire lower jaw. The superior end of the ceratohyal is curved upward and while it doubtless contains the elements of the epihyal and interhyal, the latter are as yet undifferentiated from the substance of the cartilage.

Larval branchial apparatus: (Fig. 59). Four basibranchials are sharply demarcated, the fourth one twice as long as the others and giving rise to the third, fourth and fifth branchial arches. The first, second, third and fourth arches are very similar in general appearance, and the first and second hypobranchials identical in size and shape. The third hypobranchial, while of the same size as the others, is already somewhat differentiated, exactly as in adult fish: Instead of being attached to the ceratobranchial by one end, a rounded, sunken articulation with that bone is shown. The fourth and fifth ceratobranchials lack the basal element, the fifth being less than one-half as long as the fourth and shows no further elements at its superior end. The first, second, third and fourth epibranchials are visible only as short bits of cartilage which soon die out in the surrounding tissue. There is no trace whatever of pharyngeals.

Viewed as a whole the lateral aspect of the head of the larva presents a startlingly apparent—although purely adventitious—indication of the elements of ten successive arches: the true jaws, the palato-pterygoid, the quadrato-hyomandibular, the preopercular, the hyoid, and the five true branchial arches. This false appearance is brought about by the close similarity in shape, size and angle of the ten structures and is of course completely lost during the development into the post-larval stages.

Larval pectoral and pelvic girdles: The elements of neither of the fin girdles are distinguishable.

Larval vertebral column: (Fig. 61A, a). The vertebrae are almost cylindrical and the individual centra are not always clearly to be distinguished from their neighbors. In a larva of about 20 mm in length a vertebra from the center of the body measured .27 mm in both length and maximum diameter. There is a decided decrease in size toward the base of the caudal fin. No appendages are discernible.

Larval Digestive System: (Figs. 62A, B; 63A, B; 64A, B; 65A, B).

The alimentary canal is 82 per cent as long as the fish. Behind the pectoral or cardiac region the gut is but partially enclosed in the body cavity, the ventral half supported only by the most delicate of membranes and forming a bulge along the abdominal surface. Beneath the dorsal fin, the gut emerges entirely, swells to twice its anterior diameter, and for the posterior one-tenth of its length is completely external, projecting backwards well beyond the end of the caudal fin. This exterior part is closely applied to the ventral portions of the body and caudal fin. It is attached intimately to the body behind the dorsal by a narrow membranous area, and again posteriorly to the base of the caudal fin. Between these points however it is free, and it is here that the rudiments of the anal fin are appearing.

The oesophagus is 1.4 mm long by .06 mm average breadth and extends to the tenth myomere. The anterior third lies in the midst of the body, above the heart, but behind this begins the pendulous portion noted above. Its middle part shows a valvular construction, composed of several swellings alternating with constrictions. The rudimentary liver, which is a small mass of granular substance .3 mm in length, curls upward close against the posterior fifth of the oesophagus, from the eighth to the ninth myomeres. At the tenth myomere the anlage of the stomach is visible, a minute white papilla about as broad as long (.05 mm) arising from the left side of the gut. There is no trace of caeca in the short, slightly constricted pyloric region which, to the right of the stomach, connects the oesophagus with the intestine. From the small swelling at the anterior tip of the intestine a long and thread-like bile duct (.85 mm) joins the gut with the posterior tip of the gall bladder. The latter is about as long as the liver and lies far in front of it, immediately behind the heart. Connections between liver and bladder are not found. There is no trace either of pancreas or spleen. From the pyloric region the gut, always slightly broader than the oesophagus and increasing in diameter posteriorly (from .07 mm in the middle portion to .14 mm in the protruding end) extends straight backwards until it leaves the body at a broadly obtuse angle.

Larval Reproductive System: Neither gonads nor external genitalia are visible.

Post-Larva: During the post-larval stage the optic nerve in the eye-stalk, with its accessory nerve and muscle fibers, is gradually absorbed, pulling with it the eye-ball. Under the strain the carti-

laginous rod, no part of which is absorbed at this time, rips out from the common sheath of the stalk and, still firmly attached both to the base of the eye-ball and to the frontal cartilage, bows over and gradually coils down into the open front of the eye-socket, well behind the nares. Although no change is visible from gross examination, yet the cartilaginous eye-stalk—stiff and resilient when functioning—must undergo some internal tissue alteration to become pliable enough to coil down and into its final grave in the anterior part of the cranial eye-socket. This spiral is neither covered with epidermis nor absorbed, until adolescence. In the youngest of the post-larvae, a male, the optic nerve is but slightly shrunken and consequently the distal end alone of the cartilage is affected, bending backwards at a right angle (Fig. 53B, B′). Partially formed serial organs are faintly visible in this specimen and the masculine post-larval characters (p. 159) developed in proportion. A somewhat older male is described in the pages following: The female treated immediately below, although the youngest post-larva of that sex in the collection, is still older, but because it is of the unspecialized sex it is described in advance of the male of the corresponding stage.

Post-larval Female Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 23,941; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1337; October 29, 1931; 9 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 45 mm.

Post-larval Female Measurements and Counts: Total length 48.5 mm; standard length 45 mm; depth 1.4 (in length 32.1); head 4.3 (in length 10.5); eye, horizontal, .8 (in head 5.4, in length 55.5); eye, vertical, 1.3; snout, to cartilage, 1.4 (in head 3.1, in length 32.1); snout, to iris, 1.8 (in head 2.4, in length 25); snout to pelvic 18.5 (in length 2.4); dorsal origin to caudal base 10.1 (in length 4.5); anal origin to caudal base 9.3 (in length 4.8); pectoral length 1.1; pelvic rays 6; pelvic length .7; dorsal rays 64; anal rays 45; post-orbital .2 (in head 21.5, in length 225); barbel 2.2 (in head 2); branchiostegal organs 14; serial photophores: lateral series, O–V 23, V–A 32; ventral series, I–V 34, V–A 32, A–C 17.

Post-larval Female External Characters: (Figs. 49C, 54A, A′). General pigment is practically absent, although there is an exceedingly fine dusting of microscopic brown specks. There are 72

blotches along each side and 7 small spots in the mid-line of the isthmus, while the protruding tip of the gut is laterally and distally pigmented.

The body is of typically Stomiatoid post-larval form, relatively deeper than in the larva, with the highest point toward mid-length and the caudal region much thicker than in the adult female. In other proportions too the post-larva is a perfect intermediate form: the caudal peduncle is mid-way between the minute tail of the larva and the long one of the adult, while head and snout, though much reduced compared with their early proportions, are still much longer than in the mature fish.

The maxillary reaches the eye proper (i. e. behind the cartilaginous stalk) and the mandibular angle falls at the vertical from the middle of the eye. Due to the nearly complete absorbtion of the external portion of the optic nerve the eyes are drawn close to the head, although they are loose in their large sockets. In the anterior parts of these cavities, between the nostrils and the eyes, the cartilaginous stalks are coiling down into their final positions before dissolution, each stalk forming a series of four or five loose kinks which are still completely external, above the level of the snout. The proximal and distal ends are as yet firmly attached to the skull and eye-balls respectively. The eyes themselves are still vertically elongate, directed obliquely forward.

Traces of larval denticles are found in the premaxillary only; on the other hand there are two or three rudimentary, exceedingly short, true teeth in each jaw.

The opercles are very short, covering only the most anterior of the gill arches.

The pectorals are still large (over a millimetre in length from base to tip of raylets) and fully formed. The tiny pelvics have all of the rays clearly distinguishable. The dorsal has only a third the relative extent of the adult, although all of the rays are formed and the anterior ones already have considerable spaces between them. The anal also has the full number of rays; it occupies three-fifths as much space as in the adult and commences slightly behind the dorsal origin. Its more anterior rays are exceedingly short; their development seems to have been retarded by the backward extension of the gut in earlier stages, which shows its effect even at this point, when the intestinal tip alone remains external. Both fins have firm, con-

tinuous bases which are easily detached from the surrounding skin with the rays intact; these are undoubtedly connected with the tremendous forward migration of all but the most posterior finrays. The lateral spines of dorsal and anal are discussed in connection with the osteology. The caudal fin is now of adult form—bilobed, with the lower half the longer and all of the rays strongly developed. The fin is contained about 13 times in the standard length, as opposed to some 33 times in the adult female.

Traces of finfold are present ventrally, but the only conspicuous fold lies along the middle of the dorsal profile; here it is about equal in height to the maximum depth of the fish.

The antorbital organ although small is a perfectly formed, obviously functional, double-centered photophore, pointing both down and up as usual among Stomiatoids, at least in the young; it is placed directly beneath the anterior attachment of the cartilage stalk. The postorbital lies beneath the middle of the eye itself, above the mandibular angle. In both organs the pigmented sheath is well developed, although less so in the postorbital. In maximum length the latter is scarcely greater than the antorbital; actually it is half as large as in the mature 267 mm female subsequently to be described, but relatively it is three times larger. Subdermally a slender strand connects the two post-larval organs. The short barbel is perfectly white with a short, thick stem and the component parts of the complex bulb of the future very roughly blocked out; all is quite opaque, with none of the translucency of the delicate flanges of the adult. The opercular, branchiostegal and serial photophores are all completely developed. The caudal lights are indicated, though indistinctly. Luminous granules are present in small quantities on the unpaired fins, but there is no trace of jaw luminescence or of lesser body photophores.

Post-larval Female Osteology: (Fig. 61B). There is no trace of ossification in cleared and stained post-larvae. In conformation the elements of the skull and vertebral column are, as is to be expected, less than half-way between those of larvae and adult females.

Post-larval Female Digestive System: (Figs. 62C, 64C). The gut still bulges ventrally, although it is completely covered by true abdominal epidermis. The tip of the intestine alone projects, lying close beneath the first, short, still repressed, anal rays; this portion is swollen slightly, as in the larva. Due to the elongation of the

caudal peduncle since the larval stage, the gut is now only 70 percent of the standard length. The intestine is broader than the oesophagus as in the larva; in the adult female the reverse is true. The tiny stomach, however, is already wider than either oesophagus or intestine, just as in mature fish.

The oesophagus is straight and unconstricted, 4.8 mm in length, relatively a little longer than in the larva. The organs of the pyloric region differ from those of the late larva (with the large liver) in the following respects: The stomach is much longer (2 mm, in standard length 22.5), of characteristic elongate shape and rather a continuation than an appendage of the oesophagus; in all probability, however, it is not yet functional. A pyloric arm now definitely joins stomach and intestine. From this two very short (.2 mm) but characteristically shaped caeca protrude. The bile duct (.6 mm) is not only relatively but actually much shorter than in either small or large larvae, but the bladder actually and relatively is larger (over a millimetre in maximum diameter). The small, oval spleen (.2 mm) is visible against the anterior end of the intestine, immediately above the bile duct. The liver (1.6 mm in length) although comparatively a little smaller than in the larger larvae, is broader, enclosing all except the most dorsal side of the oesophagus. Its most posterior tip, on the left as always in this species, barely reaches the origin of the stomach, as in females of all stages. The pancreas is not visible. There is as yet no pigment in any part of the gut or body cavity.

Post-larval Female Reproductive System: The gonads are minute inconspicuous threads. A gonopore is plainly visible on a small, separate papilla behind the anus.

Post-larval Male Trawling Data: All of the characters except those of the skeleton are based upon from the following specimen: Department of Tropical Research No. 21,802; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1122; August 3, 1931; 12 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 40 mm.

Post-larval Male Measurements and Counts: Total length 43 mm; standard length 40 mm; depth 1.1 (in length 36.4); head 4.3 in length 9.3); eye diameter, lateral, .74 (in head 5.8, in length 52.7); eye diameter, vertical, 1.1; distance from external base of optic nerve to apex of lens 2.9 (in length 13.8); snout 1.9 (in head 2.3, in length 21.1); maxillary 1.3 (in head 3.3); dorsal origin to caudal base

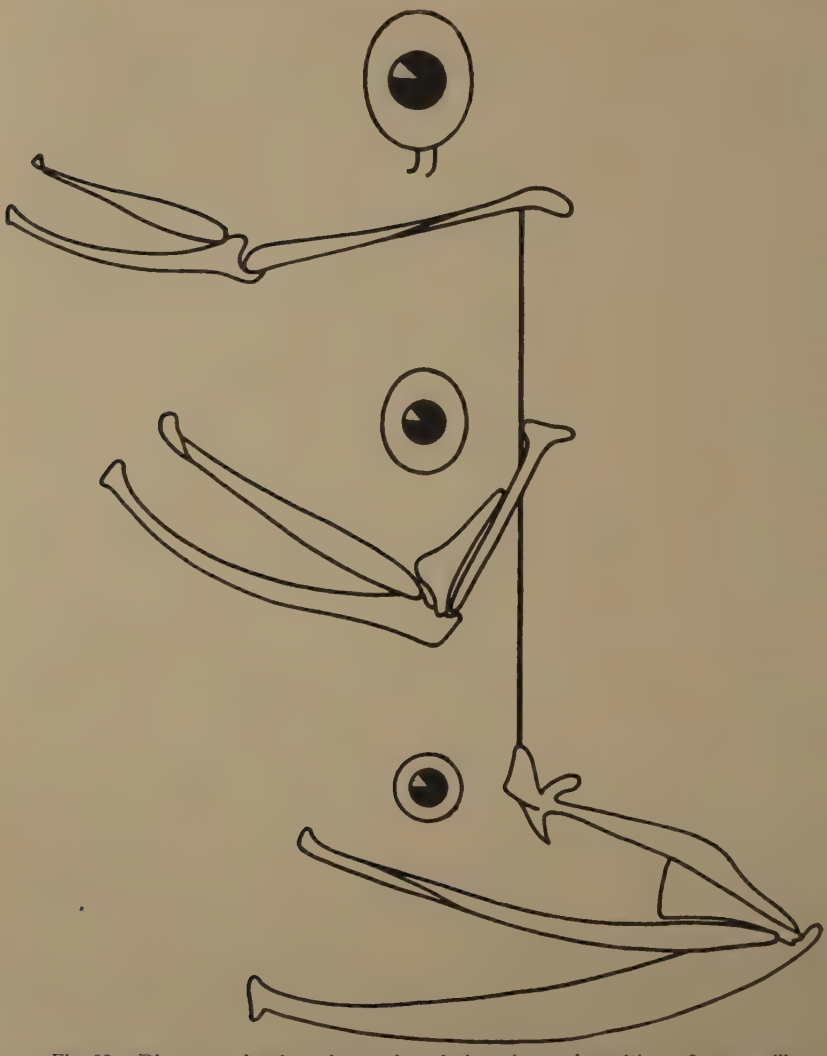


Fig. 60. Diagrams showing change in relative size and position of premaxillary, maxillary, mandible, quadrate and hyomandibular during development. Top figure, larva; middle, post-larva; bottom, adult female. The pivotal point throughout is the junction of the head of the hyomandibular with the pterotic. The eye is shown in exact position and relative size.

7.2 (in length 5.6); anal origin to caudal base 4 (in length 10); dorsal rays 55; anal rays 35; external end of gut 2.3; postorbital .32 (in head 13.4, in length 125); serial photophores: branchiostegals 12 to 13; lateral series 41; ventral series, I–A 70, A–C 0.

Post-larval Male External Characters: (Figs. 50C; 53B, B′; 55A, A′). No general pigment whatever is developed, although the head is less completely transparent and the body more opaque than in the larva. The lateral blotches number 66 in this specimen, and there are the usual half-dozen mid-line spots on the isthmus. On each side of the projecting termination of the intestine closely crowded chromatophores form an almost solid line, and the extreme tip of the intestine is similarly pigmented.

In general form this male post-larva does not differ from the slightly older female except that, as is to be expected, the caudal peduncle is not as long and the head is relatively larger and more larvoid in character, with the dorsal contour still horizontal instead of depressed. As in the female, the arching of the snout has commenced, bringing the jaw bones lower in relation to the eye, although the top of the snout itself is level with the top of the head. The jaws are intermediate between the larval and female post-larval types, the premaxillary still not overlapping the maxillary which extends only two-thirds of the way to the base of the eye-stalk and the mandibular angle falling almost beneath the cartilaginous rod. The nostrils are about midway between the tip of the snout and the base of the stalk, placed laterally.

The eyes are at a most interesting intermediate stage of the stalked phase, as the optic nerve and most of the muscles, tactile nerves and so on have about two-thirds of their former length absorbed, with the eye-ball still firmly attached to their ends, while the anterior, cartilaginous rod has burst completely from the stalk sheath and forms a pendulous loop.

In the premaxillaries and mandible the majority of larval denticles persist (6 in each of the first bones, 8 in each half of the second), but in the maxillaries only several remain in each side, very loose and asymmetrically spaced. There is no trace of true teeth.

The operculum is undeveloped.

The pectorals, although they are actually larger than in the larva, are relatively smaller, but throughout structurally similar, consisting of column, pad and raylets. There is no sign of even

rudimentary pelvics. The dorsal now shows a typically adult number of rays, as in the female, but they are crowded closely together and though occupying relatively two-thirds as much space as in the larva, the base of the fin is only a third as long compared with the standard length as in the adult. The anal has thirty-odd rays well developed, as opposed to the ten rudimentary elements of the larval anal, yet the fin is not adult in either ray number or extent, as, like the dorsal the base occupies less than one-third as much space as in the mature male. In accordance with a well marked sexual character unaffected by age, the fin base is much shorter than in the post-larval female. The caudal fin is well formed with distinct rays, a moderately deep fork, and a ventral lobe slightly longer than the dorsal one; the fin is however shorter than in adult males (contained about 13 times in the standard length as opposed to 8 to 11). In the female the opposite is true, the tail of the young being longer than in the adult.

Finfolds are rudimentary except along the middle of the back, where the fold equals the maximum body depth.

Antorbital and postorbital lights are both distinguishable, though rudimentary and with no pigmented cup. The postorbital is relatively and actually less than a fourth as large as in adult males, but already in both respects it is larger than in females of any age. It ends close to the vertical from the anterior edge of the cartilaginous eye-stalk. Not even a stump is found in the region of the female barbel. Of the serial photophores the most developed are those of the ventral series, but even in these the pigmented frames are only partially developed and the A–C series is completely lacking. The lateral serial lights are much smaller and less distinct, dying out completely fully twenty myomeres in front of the anal fin. The anterior one or two branchiostegal organs are undeveloped also. Probably none of the serial lights is as yet functional, although in slightly older male post-larvae they all showed a distinct violet hue when fresh. The caudal lights are rudimentary, but a moderate amount of luminous granular material is already present on the unpaired fins.

Post-larval Male Osteology: (Fig. 61b). As in the females of this stage, there is no trace of ossification in cleared and stained post-larvae, while in general conformation the cartilaginous elements of the skeleton are less than half-way between those of larvae and adult males.

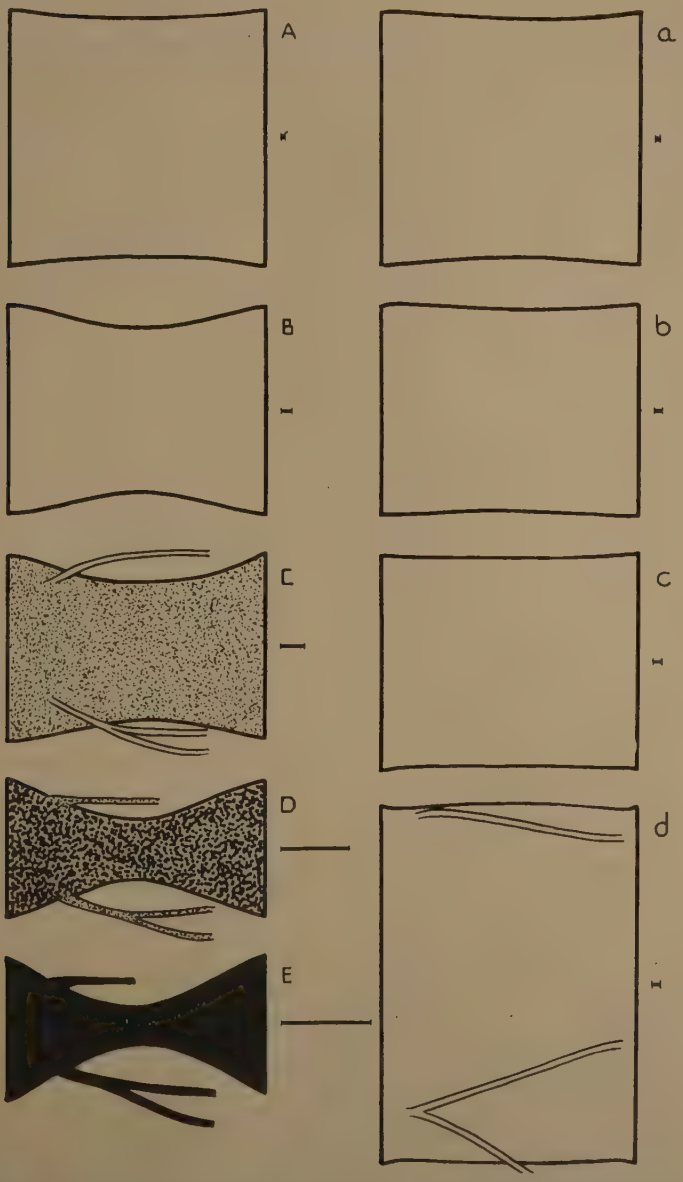


Fig. 61. Development of centra in females (left column) and males (right column). A and a, larvae, standard lengths 25 mm; B, female post-larva, 48 mm; C, female transitional adolescent, 90 mm; D, female adult, 267 mm; E, female adult, 350 mm; b, male post-larva, 45 mm; c, male adolescent, 35 mm; d, male adult, 32 mm. E is from *I. panamensis*, remainder from *I. fasciola*. Relative amount of ossification is indicated by shading, relative length of the vertebrae by the adjacent transverse lines.

Post-larval Male Digestive System: (Figs. 63C, 65C). The intestine still bulges ventrally, although it is well covered by abdominal epidermis, but the gut tip is relatively much shorter than in the larva, not reaching the end of the anal fin. The entire gut is correspondingly shorter—only 78 percent as long as the fish, opposed to almost 90 percent in young larvae. In contrast to the post-larval female there is little change from the larval organization of the various parts of the digestive system: the oesophagus still has one conspicuous bulge, the bile duct remains elongate, there is no trace of either caeca or spleen and the liver is still narrow and of a similar length to that of the late larva. In the breadths and proportions of the various sections of the gut itself, however, post-larvae of both sexes are very similar. The system is still functioning throughout, as shown by the remains of food in both oesophagus and intestine.

Post-larval Male Reproductive System: The testicles are clearly visible under low power magnification, though of small calibre compared with the intestine (the opposite is true in adult males). They measure .1 to .2 mm in diameter, and except anteriorly are located lateral rather than dorsal to the intestine. They originate well behind the stomach, at the fourteenth myomere, the left gonad slightly in advance of the right, as in mature specimens of both sexes. The sectional character of the testicles of adult males is not apparent, nor is the lace-like network of pigment found in the outer testicular membrane of more advanced specimens.

The intromittent organ is rudimentary, consisting of a small papilla behind the anus.

Transitional Post-larval Female and Adolescent Male: In appearance the transitional post-larval female corresponds to the adolescent male, as explained on p. 158. These periods are evidently short, though definite, in the development of both sexes, when the adult shapes are being rapidly assumed and the shrinking process is in full swing. Typical female and male examples are described below.

Transitional Post-larval Female Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 16,842; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 792; July 8, 1930; 10 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 48 mm.

Transitional Post-larval Female Measurements and Counts: Total

length 51 mm; standard length 48 mm; depth 2.1 (in length 22.9); head 4.2 (in length 11.4); eye, horizontal, 1 (in head 4.2, in length 48); snout 1.1 (in head 3.8, in length 43.6), maxillary 3 (in head 1.4); snout to pelvic 18.5 (in length 2.6); dorsal origin to caudal base 27 (in length 1.8); anal origin to caudal base 17.1 (in length 2.8); pelvic rays 6; pelvic length 1.2; dorsal rays 64; anal rays 42; postorbital .25 (in head 16.8, in length 192); serial photophores: branchiostegals 13 to 14; lateral series, O–V 23, V–A 32; ventral series, I–V 34, V–A 32, A–C 17.

Transitional Post-larval Female External Characters: (Figs. 49D, 54B). The outer epidermis is fairly thick, with about half of the adult amount of pigment—that is, the fish is dusky brown with only the snout and jaws pale. There are 68 lateral, subdermal pigment spots. The subisthmal spots have almost vanished, and intestinal pigment persists only as a black ring encircling the anus.

This young fish is of about adult proportions as far as trunk and caudal peduncle are concerned, relatively deeper than the post-larva, with the maximum depth at the shoulder instead of near the middle of the length as in earlier stages. The tail also is slimmer, though not as reduced as in the mature female.

The head, however, is still large, as are the eyes. The latter are firmly fixed in their sockets, with the lenses covered by membranes connecting with the orbits, and they are round, not vertically elongate as in earlier stages; the posterior half of each iris is broader than the anterior. The stalks, traceable externally by pre-orbital bumps, are completely and tightly coiled down in cavities beneath very thin coverings of skin. The original attachments to skull and eye-balls persist. The snout is proportionately shorter than in the post-larva, though longer than in the adult. The premaxillary ends at the vertical from the anterior part of the eye, the maxillary an eye's diameter behind the orbit, and the mandibular angle slightly behind this—in all three bones a great advance is represented over the post-larval stage.

The teeth are about half developed, both in number and in relative length. In both premaxillaries and maxillaries are several teeth, and 9 or 10 are developed in each half of the mandible. In each jaw the longest teeth are in the positions of the longest fangs of the adult. In the lower jaw the arrangement is not entirely symmetrical.

The opercles are incomplete, the posterior gill arches being uncovered.

Of the large larval pectoral only a low, rayletless nodule remains, almost as well pigmented as the skin. The pelvics are short, the rays distinct and rather thickly webbed.

The dorsal is intermediate in the length of its base between the post-larval stage, where it commences only a little in front of the anal, and the adolescent, where it has reached its final, adult position above the pelvics; in the present specimen it is far in advance of the anal, but well behind the pelvics. The rays are, of course, all formed, as in the post-larva. The anal is of nearly adult extent. The caudal is contained 16 times in the standard length, making it twice longer relatively than in the adult female, but shorter than in the post-larva.

Of finfolds only traces remain except above the pelvics in front of the dorsal fin. Here there is a large, fleshy frill which is the result of the extension of the dorsal rays forward along the back: In its course the expanding fin has shoved ahead of it the dorsal finfold (always the deepest portion) before it could be absorbed; consequently it has accumulated in the frill-like tissue just described, disappearing even more slowly due to the local concentration of its mass. This accounts for its persistance far into the adolescent stage, to a period when other fishes have long since lost all trace of this juvenile character. In the present specimen, this portion of the fold measures 1.5 mm in length, is half as high and has a posterior dark spot.

The antorbital apparently has only the dorsal centre functional, as the lower part of the organ is covered with skin. The postorbital is placed under the posterior margin of the eye, far in advance of the mandibular angle, instead of above it as in the post-larva. The barbel has been broken off short in this specimen, but in other comparable ones it is longer and slimmer than in the post-larva but still imperfectly formed and lacking in pigment. The serial organs, as in the post-larva, are fully formed and in this specimen retain tinges of violet even after three years in alcohol. Both caudal lights are partially developed and there is a moderate amount of luminous granular material on the unpaired fins, but no trace as yet of luminescence in the teeth, of photophores along the first pelvic ray, or of lesser head and body photophores.

Transitional Post-larval Female Osteology: There is no ossifica-

tion. The cartilaginous elements in shapes and relations show little advance over those of the post-larva.

Transitional Post-larval Female Digestive System: (Fig. 62D). The intestine is fully enclosed within the body cavity save for a vestigial external tip. Due to the increased length of the caudal peduncle the gut now measures only 62 per cent of the standard length, or little more than in the adult. Except for a small amount of pigment and an enlarged stomach the digestive organs are of the same size and in the same positions as in the post-larva. The stomach, still very short, measures 3.5 mm (13.7 in length of fish). The oesophagus and proximal portion of the stomach have a thin sprinkling of pigment, but on stomach's distal half and over the coelomic lining is only the faintest dusting of minute chromatopores.

Transitional Post-larval Female Reproductory System: The gonads are rudimentary. There is a distinct gonopore on a papilla behind the anus.

Adolescent Male Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 14,988; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 576; May 14, 1930; 10 miles south of Nonsuch Island, Bermuda; 700 fathoms; Standard length 35 mm.

Adolescent Male Measurements and Counts: Total length 38.5 mm; standard length 35 mm; depth 1.5 (in length 23.3); head 3.9 (in length 9); eye 1 (in head 3.9, in length 35); snout 1.2 (in head 3.3, in length 29.2); maxillary 2.6 (in head 1.5); dorsal origin to caudal base 15 (in length 2.3); anal origin to caudal base 9 (in length 3.9); dorsal rays 55; anal rays 40; postorbital .7 (in head 5.6, in length 50); serial photophores: branchiostegal organs 12 to 13; lateral series, O–A 50; ventral series, I–A 60, A–C 20; penis length .5 (in eye 2).

Adolescent Male External Characters: (Figs. 50D, 55B, B′). This adolescent male most nearly approaches the transitional post-larval female in appearance: the pigment is of about the same amount (the fish is half as dark as the adult female, but not much lighter than the adult male), with 66 lateral, subdermal spots; the maximum depth is typical of the adults of the species (but the deepest point on the body is toward the middle of the length—as is true even in adult males—and not at the shoulder as in all females past the post-larval stage); also as in the transitional post-larval

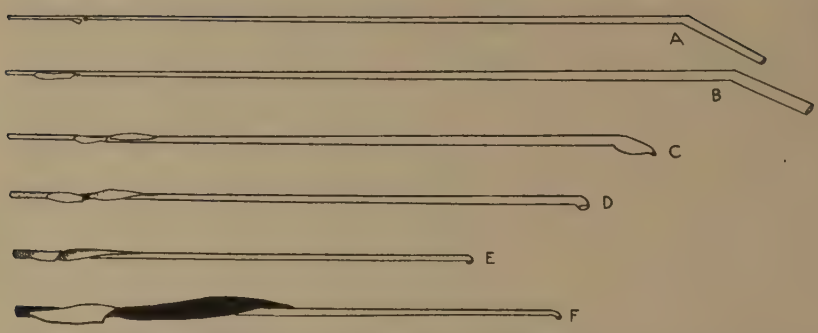


Fig. 62. Diagrams showing development of alimentary canal in female. Lateral views, left side. A, larva, standard length 16 mm; B, larva, 25 mm; C, post-larva, 45 mm; D, transitional post-larva, 48 mm; E, adolescent, 45 mm; F, adult, 267 mm. The guts are drawn to show the relation of their total lengths to the standard lengths, thus that of the 25 mm larva is 88% as long as the fish while that of the 45 mm adolescent is only 50% as long as that specimen, or relatively little over half as long as in the larva. In each case the liver is the anterior of the two organs represented, the stomach the posterior.

female the head, eye and snout are large compared with these organs in the adult female, but again they are of the final proportions for mature males. The position of the eyes too is comparable with that in the corresponding female stage, as these organs are completely sessile, perfectly round with the lens forward in each iris, and the stalks shriveled close in front of them and barely covered by thin areas of skin. The jaw bones are more larvoid than in the corresponding female, and completely edentulous.

The opercles, also as in the parallel female, are incompletely formed, the pectoral consists of a nodule only, and the dorsal and anal, though composed of typically adult numbers of rays, have not quite attained the adult male extent. The caudal is of adult male length, contained 10 times in the standard length, but it is over 3 times as long relatively as in the adult female.

A moderate sized finfold persists dorsally, with a concentrated frill of tissue immediately in front of the dorsal fin exactly as in the transitional post-larval female.

The antorbital, in its permanent position beneath the anterior corner of the eye, has now but one functional center, the upper, as in the female. The postorbital, still well separated from the antorbital, is already greatly swollen, but little over half its adult size. It commences under the posterior portion of the eye and ends well behind it, having a maximum length of about three-fourths the

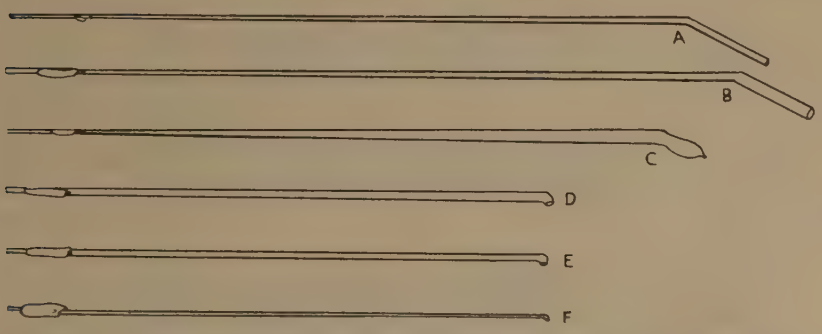


Fig. 63. Diagrams showing development of alimentary canal in male. Lateral views, left side. A, larva, standard length 16 mm; B, larva, 25 mm; C, post-larva, 40 mm; D, adolescent, 35 mm; E, transitional adolescent, 35 mm; F, adult, 38 mm. The sexually indeterminable larvae of Fig. 62 have been repeated. In each of the cuts the stomach is the minute papilla behind or beneath the larger liver.

diameter of the eye. There is no trace of a barbel. The serial photophores have the lateral series shorter by several organs than in the female, but the same is true of adult males. The ventral caudal light alone is distinguishable, but there is more granular luminous material on the unpaired fins than in the female. No jaw luminescence is developed.

Adolescent Male Osteology: (Figs. 60, 61c). There is no trace of ossification. The masculine characteristics of the bones, as described later in connection with the adult male, are beginning to be apparent.

Adolescent Male Digestive System: (Figs. 63D, 65D). The alimentary canal is entirely enclosed within the body cavity, but is traceable throughout its length by a pale colored bulge along the ventral profile. Vestiges of the larval external end of the intestine persist in the prominent anal papilla. As in the transitional post-larval female the total length of the gut is now reduced to three-fifths of the standard length, or equal to its extent in the adult male. Most important in the digestive organization is the incipient degeneration of the system: The end of the oesophagus is completely cut off from stomach and intestine by a transverse constriction, so that ingestion of food is now obviously impossible. The stomach is no longer than in the post-larva and the bile duct is reduced, bringing the gall bladder closer to the pyloric region. The liver, on the other hand, is a third again as large as in the post-larva and two rudimentary caeca are distinguishable. In average calibre the gut is about

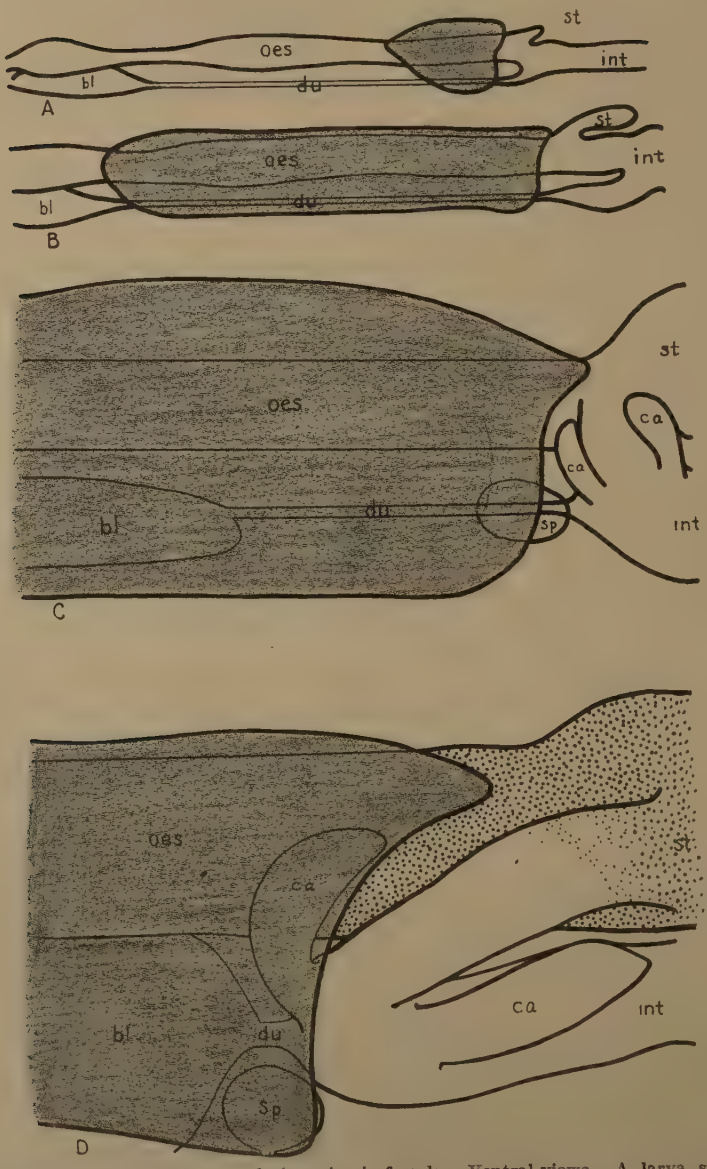


Fig. 64. Development of pyloric region in female. Ventral views. A, larva, standard length 16 mm; B, larva, 25 mm; C, post-larva, 45 mm; D, adolescent, 45 mm. The liver is indicated by the shaded portion. Abbr.: bl, gall bladder; ca, caecum; du, bile duct; int, intestine; oes, oesophagus; sp, spleen; st, stomach. (× 57).

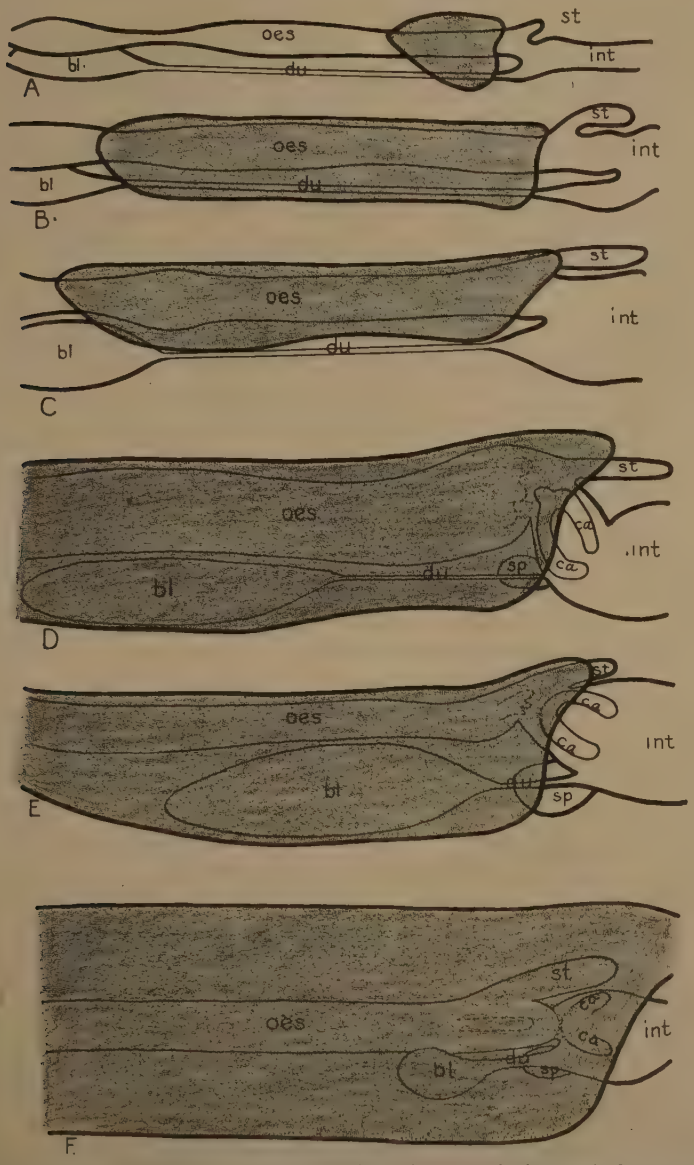


Fig. 65. Development of pyloric region in male, ventral views. A, larva, standard length 16 mm; B, larva, 25 mm; C, post-larva, 40 mm; D, adolescent, 35 mm; E, transitional adolescent, 35 mm; F, adult, 35 mm. The liver is indicated by the shaded portion. Abbreviations as in Fig. 64. (× 57).

equal to that of the post-larva, but the terminal portion is only slightly expanded. There is a small rounded spleen above the pyloric end of the bile duct.

Adolescent Male Reproductory System: The gonads are .25 mm in diameter, about equal to that of the intestine. Pigment is appearing in a series of broken transverse bands. There is still no trace of the testicular constrictions found in more advanced specimens. The intromittent organ behind the anus is unpigmented, half as long as in the adult and shorter than the first anal rays.

ADOLESCENT FEMALE AND TRANSITIONAL ADOLESCENT MALE: As explained on p. 158 the adolescent female in appearance corresponds most closely to the transitional adolescent male. It is during these periods in the lives of each that the last vestiges of larval eyestalks, pectoral fins and finfolds gradually disappear. Individual examples of both sexes are described below.

Adolescent Female Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 23,148; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1270; September 7, 1931; 10 miles southeast of Nonsuch Island, Bermuda; Standard length 45 mm.

Adolescent Female Measurements and Counts: Total length 48.5 mm; standard length 45 mm; depth 1.9 (in length 23.7); head 3.4 (in length 13.2); eye .8 (in head 4.3, in length 56.3); snout 1 (in head 3.4, in length 45); maxillary 2.6 (in head 1.3); snout to pelvic 17 (in length 2.6); dorsal origin to caudal base 28.3 (in length 1.6); anal origin to caudal base 16.7 (in length 2.7); pelvic rays 6; pelvic length 1.5; dorsal rays 60; anal rays 38; postorbital .22 (in head 15.5, in length 204.5); barbel 3.6 (in head .9); serial photophores: branchiostegal organs 13 to 14; lateral series, O–V 23, V–A 33; ventral series, I–V ca. 34, V–A 34, A–C 17.

Adolescent Female External Characters: (Figs. 49E, 54C, C′). The 68 larval subdermal spots are fading but distinct, although due to the dark general pigmentation they are faint when viewed with the skin intact. The external pigment is not however completely developed, and the jaws are still pale.

In relative depth and in size and appearance of the head this adolescent specimen agrees with adult females, but the eye and snout are both relatively still large. Inside the snout there is visible

the last trace of juvenile cartilaginous eye-stalk: all except a part of a single spiral has been absorbed.

In the jaws the teeth are developed only slightly more highly than in the transitional post-larva, being short and scattered; in the premaxillaries there are 5 or 6 pairs, 1 or 2 pairs in the maxillaries and about 8 teeth in each mandibular ramus. Both vomer and palatine are edentulous but the basi-branchials have 2 pairs of teeth, strong, long, curved and posteriorly directed—the most efficient teeth in the mouth during this period.

The opercles are practically complete.

Of the early pectoral fins only a scar remains. The pelvic is relatively not as long as in the adult, but the dorsal and anal are fully developed, the first four dorsal rays being in advance of the pelvics. The caudal, however, is still relatively two and one-half times as long as in the adult female, or about one-thirteenth of the standard length.

A small, fleshy tab, reduced compared with the same finfold remainder in the transitional post-larva, is the only trace of finfold in this specimen.

The antorbital still has a single, upper, fully functional center. The postorbital is below and behind the posterior margin of the orbit and is somewhat over three times longer relatively than in the adult, actually a little more than half as large. The barbel is slightly longer than the head, instead of more than twice as long, as in large specimens, and has the stem merely dusted with pigment. The bulb is completely colorless, with none of the details formed of the delicate flanges and filament of the adult: the translucent tissues of the older fish are fleshy and opaque in the adolescent, while the future filament is a thickly tapering projection. Serial photophores, as in previous stages, are all present and functional, and the ventral caudal light and luminous fin granules are highly developed. The upper caudal light remains rudimentary and there is no trace either of tooth luminescence or of pelvic photophores.

Adolescent Female Osteology: There is no trace of bony tissue. The elements in general, however, show advanced development, save for the still juvenile juxtaposition of the bones entering into the angle of the jaw and the conformation of the vertebrae, which still are but slightly excavated.

Adolescent Female Digestive System: (Figs. 62E, 64D). Exter-

nally there is no trace of the gut. Its total length is only 50 per cent of the standard length of the fish, and it is now relatively shorter than at any other stage of development. Compared with the post-larva, the stomach is longer, extending to a point three-fifths of the distance between opercle and pelvic, its length contained 10 times in the length of the fish; the oesophagus and dorsal anterior portions of the stomach are more densely pigmented; the liver is broader, but relatively shorter, with the left tip pronouncedly longer than the right; the caeca and the pyloric arm joining stomach and intestine are of adult form and proportionate size; the bile duct has been further reduced, drawing the bladder close to the pyloric region, and the spleen is now slightly to the right of the bile duct. There is no noticeable change in the calibre of the gut, save that it is scarcely expanded distally.

Adolescent Female Reproductive System: The gonads are as yet rudimentary.

Transitional Adolescent Male Trawling Data: All of the characters except those of the skeleton are based upon the following specimen: Department of Tropical Research No. 18,009; Bermuda Oceanographic Expeditions of the New York Zoloogical Society; Net 854; September 6, 1930; 10 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 35 mm.

Transitional Adolescent Male Measurements and Counts: Total length 38.2 mm; standard length 35 mm; depth 1.8 (in length 19.4); head 3.7 (in length 9.5); eye .97 (in head 3.8, in length 36.1); snout 1 (in head 3.7, in length 35); maxillary 2.3 (in head 1.6); dorsal origin to caudal base 19 (in length 1.8); anal origin to caudal base 9 (in length 3.9); dorsal rays 51; anal rays ca. 33; postorbital 1 (in head 3.7, in length 35); serial photophores: branchiostegal organs 12; lateral series, O–A 43; ventral series, I–A (end of lateral series) 50, A–C 25; penis length .6 (in eye 1.6).

Transitional Adolescent Male External Characters: (Figs. 50E, 55C, C′, C-). The immature male does not differ significantly from the mature specimen subsequently to be described except in the following particulars: The skin is not as deeply pigmented as in the adult; the snout is not as highly arched; traces of eye-stalk remain beneath the skin of the snout; the mandibular angle falls at a point only about half the width of the eye behind the orbit, instead of about twice the eye's diameter as in the adult; there is a trace of dorsal fin-

fold especially concentrated in a frill-like tab in front of the dorsal; the postorbital is about three-fourths as large as in the mature male, connected with the antorbital only by a dark bridge of pigment, the luminous center commencing far back under the posterior part of the eye; the lateral series of photophores ends well in front of the anal origin, instead of above the first few anal rays; and, finally, the dorsal organ of the caudal is rudimentary.

When compared with the corresponding adolescent female, the general differences between the two, as opposed to the strictly sexual, are much more apparent than in earlier stages. Especially striking are the medially thickened body, large eyes, and short jaws of the male.

Transitional Adolescent Male Osteology: In general conformation the elements of the skeleton are very similar to those of the adult male, subsequently to be described. There is still, however, no trace of ossification.

Transitional Adolescent Male Digestive System: (Figs. 63E, 65E). As in both adolescent and adult male the gut measures three-fifths of the standard length. Compared with the adolescent, the diameter of the oesophagus is reduced by the infolding of its walls at the expense of the bore; the partition between oesophagus and pyloric region is thickened; the liver is slightly longer, its posterior tip partially overlapping the still rudimentary stomach and caeca; and the bile duct is further reduced in length. Of all these changes the last alone takes place also in the corresponding, adolescent female. The immaturity of the male is shown in comparative narrowness of the liver, unshrunken gall bladder and relatively wide intestine.

Transitional Adolescent Male Reproductory System: The testicles are no larger than in the adolescent, being of the same diameter as the intestine, but the pigment now forms a fairly continuous network over their surface, instead of the former series of broken bands and the constrictions so typical of the testicles of the adult are indicated in this transitional adolescent. The intromittent organ is still short and white, but is already stiffened by attachment to the first anal ray.

Transitional Adolescent Females: (Fig. 47). The Bermuda collection contains 15 specimens which are referred to this growth stage, ranging between 48 and 161 mm. From true adolescents they differ in their dark pigmentation, being usually as dark as the adults;

in the superior dentition; in the lack of traces of eye-stalks, pectoral scars and finfolds; in the fully shaped barbel; in the practically adult size and pigmentation of the stomach; and, among larger specimens, in the advanced ossification and partial development of the gonads.

From the adult specimens the transitional adolescents differ in having the premaxillary teeth alone completely developed, those of the maxillary and posterior part of the mandible being few and very small; in having the barbel bulb entirely or partially unpigmented; in the slight ossification of the skeleton; and in the immaturity of the gonads.

It is during this stage that a bony skeleton is built up. The first areas to show ossification are the jaws, parasphenoid, hyomandibular, preopercle, frontal ridges, main opercular ridges, pectoral girdle, hyoid arch and branchial apparatus. Ossification of the vertebral column (Fig. 61C) follows, proceeding posteriorly. The posterior parts of the column and the finrays show no stain until the fish is well over 100 mm in length, while the brain case and minor elements of the head may be almost unossified even in fully mature specimens. Strengthening of the bones seems to continue throughout life.

Adult Females and Males: The adult characters of both sexes are tabulated on pp. 156–157.

The 4 adult females measure 190, 242, 267 and 270 mm respectively. The smallest of these has the transitional adolescent characters of incomplete maxillary and posterior mandibular teeth, but allowing for its small size the eggs and ovaries are relatively about as well developed as in the larger non-breeding specimens of 242 and 270 mm. The 267 mm specimen alone is in full breeding condition and is described in detail below.

A mature male with ripe spermatozoa is treated subsequent to the female.

Adult Female Trawling Data: All of the characters are based upon the following specimen: Department of Tropical Research No. 21,937; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 1137; August 6, 1931; 9 miles south of Nonsuch Island, Bermuda; 600 fathoms; Standard length 267 mm.

Adult Female Measurements and Counts: Total length 275 mm; standard length 267 mm; depth 11 (in length 24.3); least depth 3 (in length 89); head 18 (in length 14.8); eye 2.6 (in head 6.9, in

length 102.7); snout 3.5 (in head 5.1, in length 76.3); snout to pelvic 94 (in length 2.8); pelvic to anal origin 74; dorsal origin to caudal base 181 (in length 1.5); anal origin to caudal base 97 (in length 2.8); pelvic rays, left side 6, right side 8; pelvic length 16; pelvic origin under fourth dorsal ray; dorsal rays 68; anal rays 44; caudal rays XIV + 10 + 10 + VII; postorbital .4 (in head 45, in length 667.5); barbel 43 (2.4 times head); serial photophores: lateral series, O–V 24, V–A 34; ventral series, I–V 35, V–A 34 (16 to anal origin), A–C 14.

Adult Female External Characters: (Fig. 49F, 66). In the fresh specimen the skin was dark brownish black, as was the barbel stem. The core of the barbel bulb also was dark, with the translucent white, enveloping membranes speckled proximally with black; the anterior filament was pale lemon yellow. All of the serial photophores were blue violet, those of the ventral series being set in gilt frames. Both upper and lower caudal lights were bright golden yellow. Even in the comparatively pale, preserved specimen there are subdermally faint traces of the lateral larval chromatophores as well as a partial general wash of dark pigment.

The characteristic extreme slenderness of the genus is very evident in this large example, as is the gradual and symmetrical tapering from the shoulders to the much attenuated caudal base. The crown of the head is scarcely raised above the shoulders, the moderately short snout sloping from here rather abruptly to its blunt tip. The lower jaw curves slightly upwards, projecting a little beyond the tip of the premaxillary. The eye, well developed but relatively smaller than in preceding stages, does not interrupt the dorsal profile, and neither internally nor externally is there the least trace of the larval stalk of cartilage. The nostrils are placed high on the snout, slightly nearer to its tip than to the eyes.

All except the smallest of the teeth are depressible and bicuspid, as is typical of the genus, very unequal in length, and show a tendency to be arranged in groups, the members of each increasing in size posteriorly. In the left half of the mouth the numbers of teeth are as follows: The premaxillary holds 11, the seventh, third and eleventh respectively the longest; the maxillary has two anterior series of erect teeth of 6 and 4 teeth each, the former in a graduated row, the latter much smaller and of nearly equal size; following these are several minute, erect denticles. The mandible holds 29 teeth, the fifteenth, sixth and thirteenth longest, larger than any of

Fig. 66. Heads of adult female, standard length 267 mm, and adult male, standard length 38 mm, showing relative size. (× 4.5).

the upper teeth; the last 10 are small, in two series of 6 and 4 which correspond to the anterior maxillary teeth, although they are not as large. In addition there are several small replacement teeth. On the right side of the mouth the number and relative size of the teeth are very similar; the chief differences are the presence of an extra, minute, anterior, premaxillary tooth and the shortness of the fifteenth mandibular fang, which is obviously replacing a lost tooth. There is a single pair of teeth on the vomer, 2 teeth on each palatine and 4 pairs on the basibranchials. Finally, on each of the third pharyngobranchials are two groups of 4 to 6 and 3 to 5 teeth each.

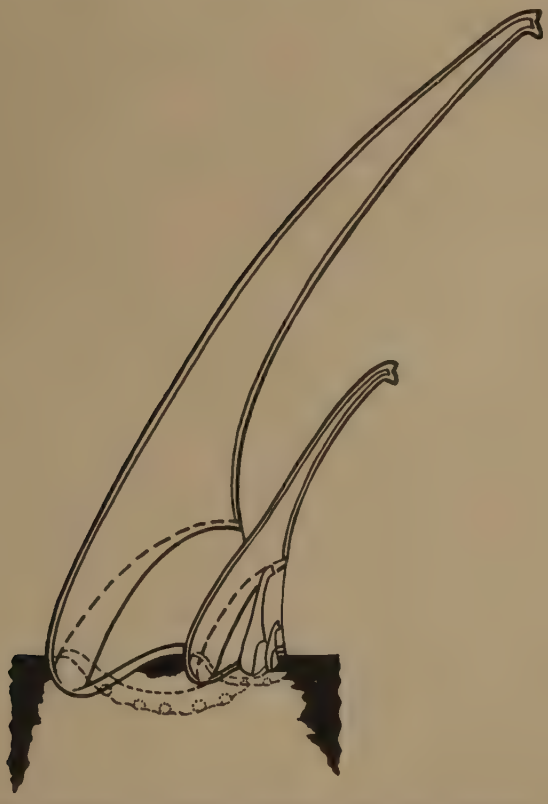


Fig. 67. Two fangs and two small replacement teeth from mandible of adult female, showing luminous basal cores and row of pores along inner edge of base. (× 20).

Within the translucent base of each tooth a considerable amount of bluish, luminous substance is visible (Fig. 67). After clearing and staining it is seen that this is held in a large, triangular cavity occupying more than the posterior half of the base of the tooth and thrusting far into it, its apex reaching one-fourth (in large fangs) to one-half the distance to the barbed tip. It recalls luminous buccal mucous which covers the teeth in some deep-sea fish. This internal dental substance must combine the qualities of supplying the material for tooth replacement and growth with luminosity. The sides of the tooth overlap the inner and outer margins of the jaw, so that a strongly arched floor is formed. Completely encir-

cling the very base of the vertical walls is a narrow rim of especially firm bony tissue; on the inner side this is punctured with about half a dozen pores, giving access to the cavity. All of the cavity boundaries except this basal rim and the anterior and upper walls (which are of the bony substance of the tooth proper) are of a delicate, easily ruptured, perfectly transparent, cartilaginous material. The tooth itself is faintly striated with alternating series of short, vertical lines.

All trace of a pectoral nubbin has disappeared. The pelvics originate under the fourth dorsal ray, and though the rays are rather strongly developed they are unwebbed and quite short. Along the first ray is a row of graduated, round, white spots, largest proximally. Except for the luminescence possibly shed by these organs, the pelvic fins cannot be of much practical value. Due to their comparative feebleness their use as claspers of the male during copulation seems out of the question. On the right side of this individual fish, 2 extra pelvic rays are developed behind the normal group of 6; these abnormal rays are shorter than the rest (which are of approximately equal lengths), separated from them and from each other by distinct spaces and are quite feeble. All except the last dozen or so of the dorsal and anal rays are separated by broad and nearly equal spaces; the most posterior rays, however, become successively more closely crowded. The webbing of these unpaired fins is perfectly transparent and appears exceedingly delicate, but is actually reasonably strong. Anteriorly it does not reach the tips of the rays. The caudal fin is contained 33.4 times in the standard length, with the fork moderately deep and the lower lobe considerably the longer. The long, true terminal caudal rays have single rows of dark dots, possibly rudimentary photophores, in the webbing between each two rays; these organs are completely lacking between the nine central, short rays which form the base of the fork. The luminous material close to the fin's base, subsequently to be described, prevents any spreading of the rays, and there seems very little mobility to the fin as a whole, as the elements are all very flat and soft. All of the terminal ones have the numerous cross bars of typical rays—joints which are as usual lacking in the dorsal and ventral raylets.

A trace of the antorbital photophore survives in a small crescent of luminous tissue below the lower front corner of the eye. The

postorbital is a minute round photophore facing outwards, set in a somewhat larger, black frame.

The barbel stem is fully pigmented clear to the terminal swelling; the core of the latter is dark brown, save for the attenuated tip, while the translucent, proximal envelope and expanded, basal portion of the posterior filament are speckled with brown. The anterior and posterior membranous flanges running the length of the distal half of the bulb are perfectly clear. In the fresh specimen the terminal half of the proximal, anterior filament, with the characteristic swelling of the species, was pale lemon yellow. At the base of the bulb posteriorly is a small, rounded luminous body. The general structure of the barbel, however, makes it probable that its function is tactile or receptive rather than light-giving.

The serial photophores, as well as those of the branchiostegals and the two opercular lights, were blue violet in the fresh specimen. Each of the lateral and ventral lights is set near the middle of a myomere. In the preserved fish the gilt frames of the ventral organs, so conspicuous in the new-caught state, are invisible, traces remaining only in somewhat paler skin immediately surrounding each light. All of the organs are directed obliquely downward.

Lesser lights of the head and body are few in number compared with their abundance in many of the Melanostomiatidae, but are concentrated in the same regions. They are moderately numerous on both upper and lower jaws, sparse on cheeks and opercles and absent on the top of the head. The barbel stem has a few irregularly placed, minute organs, especially distally. On the body (Fig. 68) the myomeres are outlined with single rows of closely set, microscopic organs averaging 50 to each row from dorsal to ventral profile. The myomeres themselves have a few larger lights. These tend to form a median vertical line of from 6 to 10 organs in the middle of each myomere, each line beginning slightly above the mid-line and ending above an organ of the lateral series. In some cases this vertical row continues up to the dorsal profile as a more irregular line of much smaller organs. Near each central line there are usually half a dozen or more odd organs scattered mid-laterally and without arrangement. Across each myomere between the lateral and ventral series are two rough, concentric arcs of small organs with each lateral light the center of the incompleted circles. The lower series of arcs is the more conspicuous of the two all along the body. Each arc is

composed of about a dozen organs, not equally or symmetrically spaced. In the ventral mid-line is a continuous double row of similar organs, also numbering in each row about 12 to a myomere. On the caudal peduncle the anal fin passes between the two rows, and the organs in this region are less numerous and more irregular.

There is a conspicuous line of whitish luminous tissue along the upper margin of the maxillary immediately below the postorbital light. On the body similar whitish patches alternate with the serial organs at least as far back as the pelvics, and, along the profiles, with the ray bases of the dorsal and anal fins. The row of bead-like

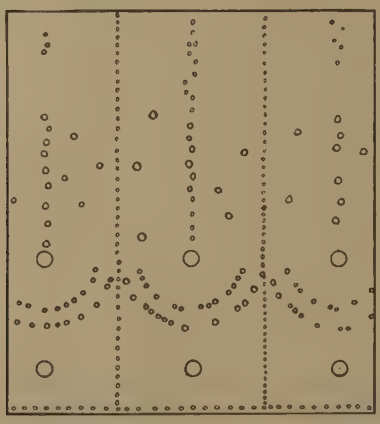


Fig. 68. Arrangement of photophores in adult female, between dorsal and ventral profiles, showing serial organs and lesser lights. From the mid-trunk region of a specimen 267 mm in standard length.

lights on the first pelvic ray has been already described. In this specimen the luminous granules which are so conspicuous on the dorsal and anal fins of the males are almost lacking.

Alternating with the bases of the twelve supra-caudal raylets are small patches of lemon yellow luminous material. Two large organs of the same substance lie at the bases of the last three rays extending downward over the flesh of the base of the caudal fin for a short distance. The whole arrangement is reminiscent of the luminous supra-caudal scales of the Myctophid genus *Lampanyctus*. The uppermost five, true, terminal, caudal rays have luminous granules between them, while the lowermost support the largest of the caudal organs; this extends for about 2.7 mm over the basal

portions of the middle lower rays, with a smaller distal finger lying ventral to the parallel from the main organ. These latter yellow organs were exceedingly brilliant in the fresh fish. The seven infracaudal raylets also have small amounts of luminous material alternating with their bases.

Adult Female Osteology: In the study of the osteology of the adult female, the 267 mm specimen of *Idiacanthus fasciola* just described has been compared, after clearing and staining, with an example of *I. panamensis* measuring 350 mm in length (see page 237 for trawling data) and similarly treated. With the exception of the shape of the vertebrae the configuration of the bones in the two species is practically identical. The smaller fish, however, although in full breeding condition, is everywhere noticeably less strongly stained, while the skull proper and the teeth—both of which show strong ossification in the larger specimen—are more faintly colored. In other respects the relative ossification of various areas is very similar in both species: The jaws, parasphenoid, frontal ridges, hyoid and branchial apparatus and the barbel bone are most deeply stained, but the palato-pterygoid arcade, preopercle, opercular ridges, pectoral girdle, vertebral column, finrays and vertebral appendages also show strong ossification. In neither specimen do the opercle, subopercle and interopercle show more than traces of stain.

The similarities in the shapes and relations of the bones in these two fish indicate that the variation in amount of ossification is due, not to specific differences, but to the continued deposition of bony matter after full maturity has been attained.

The various portions of the skeleton are described in detail below.

Adult female skull: At first glance the skull seems to be poorly ossified, even in the larger specimen, but this is due to the small size of the cranium proper and to the great length and slenderness of the principal components of the opercular and the oro-mandibular areas and of the branchial apparatus. Individually many of the bones show thorough but delicate ossification.

The cranium, viewed from above, (Fig. 69) shows an abruptly broadened posterior portion, narrowing to about one-half of the width in front of the sphenotics, thence sloping forward to expand again into the mesethmoids. In both *I. fasciola* and *I. panamensis* of the present collection the cranium is considerably broader posteri-

orly than is shown in the figure of Regan and Trewavas (1930, p. 48, fig. 20B). This distinction is true even in smaller specimens.

The elements of the broad, posterior brain case proper are strongly fused, in some cases the limits of the bones being evident rather by varying thickness of ossification than by actual lines of demarcation.

The largest element of the postorbital area is the supraoccipital. Posteriorly it curves backward over the exoccipitals, while on each posterior side the large, rounded epiotics describe a curve in its contour. Anteriorly, its exact extent is lost beneath the over-growing frontals, leaving exposed a good-sized anterior tongue and steeply sloping sides. The extreme center is marked by a mass of bubble-like mucous openings. The pterotics lie outside the epiotics, equal to the latter in area, but irregularly elongate antero-posteriorly, projecting strongly backward at the postero-lateral angles of the cranium. The sphenotics resemble in size and general shape the epiotics. They form the major parts of a pair of triangles anterior to the pterotics, the apex of each projecting sharply out on the side of the cranium.

The mid-portion of the skull, composed wholly of the frontals, is narrow only in comparison with the wide posterior area. The frontals are of great extent, the two anterior points widely divergent. Along the midline this pair of bones is closely apposed except for the central third of their length. Here they are considerably divergent. Behind this area they close up again, finally to separate, outlining the anteriorly directed tongue of the supraoccipital and sloping sharply posteriorly over the lateral extent of the supraoccipital to die out in an irregular line of ossification near the anterior edge of the epiotics. The most strongly ossified area of the entire cranium is that of the pronounced frontal ridges extending near the outer borders of the bones from the anterior tips as far back as the junctions with the sphenotics. From here posteriorly these ridges become covered tubes extending out to the very tip of the posterior projection of the pterotics.

Anterior to the frontals and hardly less strongly ossified are the two wide, lateral wings of the mesethmoid. In the center line anteriorly this bone curves abruptly downward and expands at once into a broad and almost transparent plate which covers the vomer. In no specimen are lateral ethmoids, figured by Regan and Trewavas

(*loc. cit.*) distinguishable from the surrounding tissue, even as cartilaginous elements. The nasal bones are much reduced, appearing only as two imperfect, short tubes near the center of each lateral mesethmoid wing.

Adult female palato-pterygoid arcade: (Fig. 70). The hyomandibular is a remarkably shaped bone with a trilobed head and a long slender body. The markedly ridged and strongly ossified center of the head sends a large, triangular flange upward, the flat, farthest edge of which articulates with the outer side of the pterotic. Downward and forward extends a second delicately ossified, wing-like flange while posteriorly a strong, narrow arm articulates with the main head of the opercle and the superior end of the preopercle. The remainder of the hyomandibular extends backward as a long and slender bone, slightly thickened in the mid-area and finally articulating closely with the ends of the preopercle and the quadrate. The quadrate in the shape of an elongate triangle has its superior profile closely applied along half of the elongate body of the hyomandibular. Just anterior to it, bounded above by the body of the hyomandibular and below by the pterygoid, lies the irregularly semicircular metopterygoid. Both of these bones are thin and leaf-like but decidedly ossified. The pterygoid is a long, thin, spine-like bone commencing at the lower anterior end of the quadrate; it extends forward parallel to, but at considerable distance from, the hyomandibular until it articulates with the palatine at about three-fourths of the distance from the angle of the jaw to the tip of the premaxilla. Just before its articulation it widens slightly. The palatine at its point of attachment is of equal width and then extends forward becoming narrow until it suddenly expands into a spoon-shaped enlargement at its attachment to the mesethmoid and the premaxilla. Halfway down its length it is armed with two or three pairs of strong, fang-like teeth. The vomer is small and supports a single pair of teeth slightly larger than those on the palatine. From this point backwards extends the strongly ossified, rod-like parasphenoid.

Adult female jaw apparatus: (Figs. 60, 70, 72). The bones of the jaws while slender and rod-like are strongly ossified and all of them support a powerful dentition. Each premaxillary has a pronounced upward projection at the point of juncture. From here it extends along the upper jaw for about forty per cent of its entire length.

The maxillary begins as a narrow, ossified splinter directly under the expanded portion of the palatine and extends backwards with gradually increasing surface, forming the actual edge of the jaw for the posterior sixty per cent. Throughout its length it maintains its narrow, rod-like character with very slight enlargement at its posterior attachment. For more than the posterior third of the entire length of the maxillary its upper profile is formed by the distinctly separate supramaxillary. The mandible is by far the largest and stoutest bone of the head. The dentary forms the major part, the articular showing as a broad wedge driven down the center to a distance of over half the entire length of the jaw. The angular is hardly to be detected as a separate element near the extreme inferior profile of the articulating process. For details of the dentition see page 197.

Adult female opercular bones: (Fig. 70). The opercular bones, while all present, are of the thinnest imaginable ossified tissue, being marked strongly only along their supporting ridges. From the large articular head of the opercle two strong, rod-like ridges diverge, one toward the upper edge and the other throughout its length to the posterior edge. Below this, only imperfectly demarcated, are the subopercular and the interopercular areas, continuing the delicate, membrane-like opercular contours. The preopercle on the other hand is a strongly ossified, rod-like bone extending from the posterior arm of the head of the hyomandibular and closely paralleling its body to the point of junction at the angle of the upper jaw. For about one-half of their length the two bones are firmly ossified together, separating just before the jaw angle to form a large, oval foramen.

Adult female circumorbital bones: (Fig. 69). The only structure which can be classed in this category is a supra-orbital appearing as a lateral expansion of the frontals. It is quite unossified, but of cartilaginous consistency.

Adult female hyoid arch: (Fig. 71). The upper end of the long, slender interhyal lies close to the hyomandibular, but is not definitely attached to any particular tissue, at about the beginning of its point of ossification with the opercular. The epihyal, which is only slightly longer than the interhyal, is about three times as wide and gives rise to five branchiostegals. One of these arises near the anterior end. The other four are bunched close to the articulation with

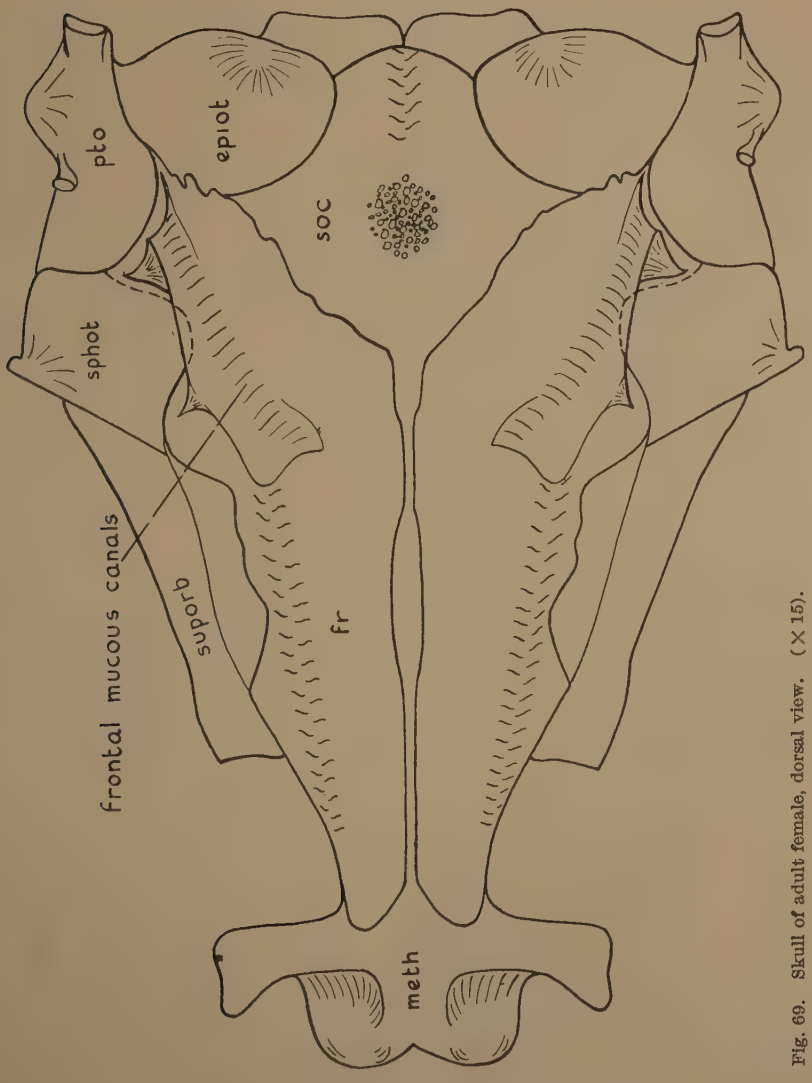


Fig. 69. Skull of adult female, dorsal view. (× 15).

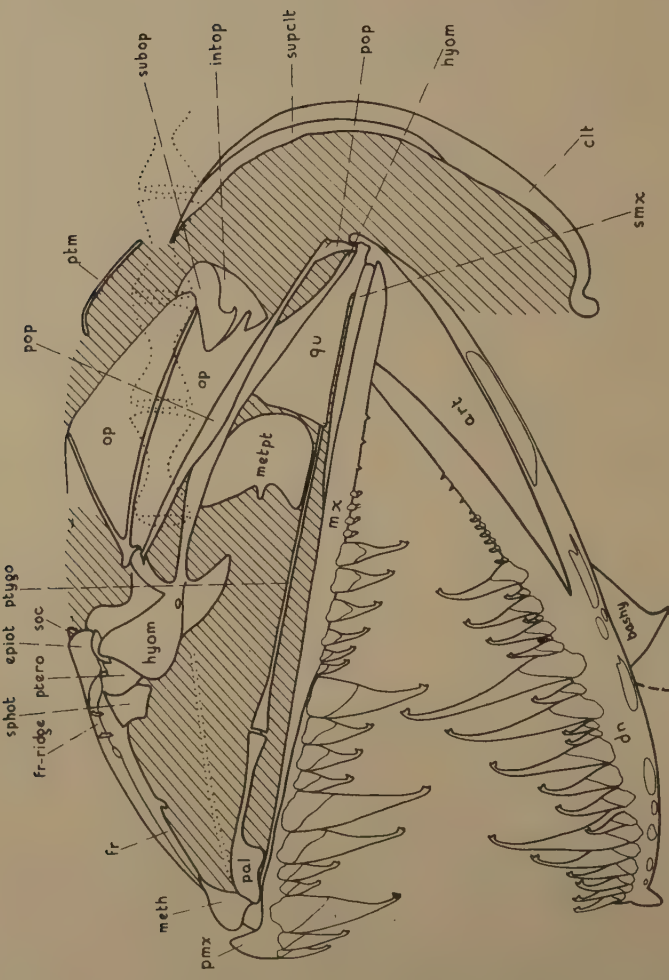


Fig. 70. Bones of head and pectoral girdle in adult female, lateral view. (× 5.5).

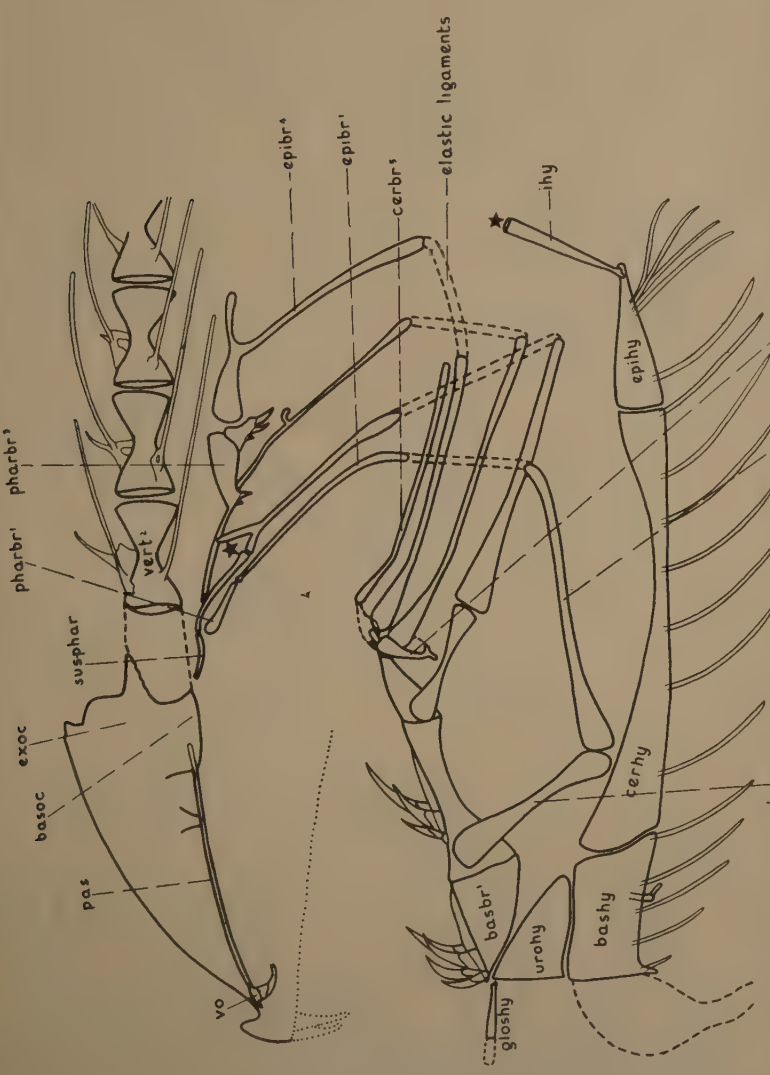


Fig. 71. Hyoid arch, branchial apparatus, and anterior part of vertebral column in adult female. The interhyal has been detached (normal position indicated by star) and the basibranchials pushed upwards in order to show all of the elements clearly. (× 5.5).

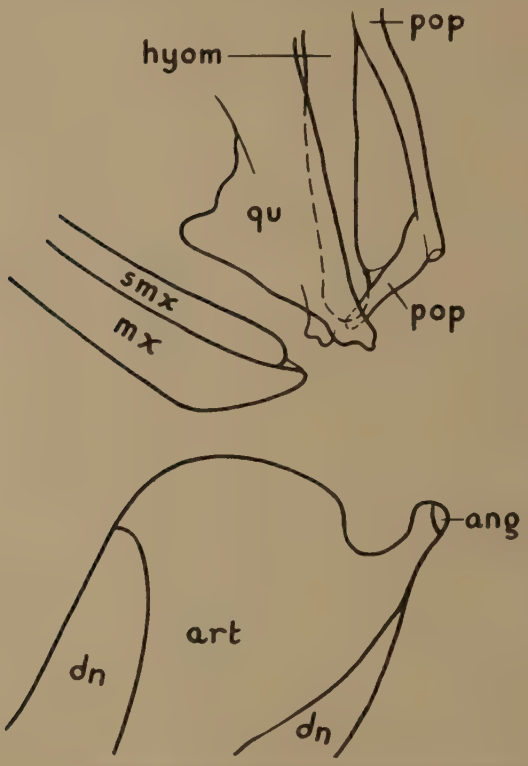


Fig. 72. Disjointed elements of jaw angle of adult female.

the interhyal and of these the posterior three seem to have but one definite point of insertion. The ceratohyal is three times as long as the epihyal, broad at both ends but gradually narrowing to an extremely slender center. It gives rise to seven branchiostegal rays. Directly in front is the basihyal, a rather broad rectangle having a curved posterior profile but vertical in front, from which springs the enlarged base of the barbel. Between the two basihyals, closely posterior to the origin of the barbel, is a single crescent-shaped supporting bone affording attachment to the controlling muscles of the barbel. Five branchiostegals arise from the basihyal. It equals the epihyal in length. Immediately above the basihyal and articulating along its entire upper profile is the urohyal, quite evenly triangular in shape. From the upper anterior angle extends forward the glosso-

hyal, which is about equal to the urohyal in length but slender and rod-like, and ossified only for its basal two-thirds.

Adult female branchial apparatus: (Fig. 71). The first basibranchial in shape and size closely resembles the urohyal and supports two pairs of slender, fang-like teeth. The second basibranchial is almost twice as long as the first, medianly slender, expanding at both ends. Near the center it also gives rise to two pairs of strongly recurved fangs. The third basibranchial is about as long as the first but much more slender, especially posteriorly. Near the posterior end of this third basibranchial there are faint indications of demarcation into a fourth. Posterior to this there is an unossified cartilaginous mass of connective tissue which from the point of view of physiological function might be called the fifth basibranchial.

Three hypobranchials are plainly indicated. The first is one-third longer than the second, both of which are similar in shape, a narrow median portion connecting expanded ends. The third is only one-half as long as the second and anomalous in both shape and position. Its rather broadly expanded base is attached to the narrow posterior neck of the questionable fourth basibranchial while its anterior end is slightly bifurcated, quite free and directed downward.

There are five ceratobranchials, all slender and rod-like with somewhat enlarged ends. The first and second are normal as to their anterior articulations. The third articulates equally with the attached base of its abnormal hypobranchial. The fourth and fifth articulate with the cartilaginous posterior extension of the basibranchial elements. Each of the first four ceratobranchials at its distal end is attached to a remarkable, slender band of elastic ligament or tissue, in each case about half the length of the ceratobranchial. These ligaments are apparently specialized characters for allowing great distension of the entire branchial apparatus, apparently an aid in swallowing prey of great size. The fifth ceratobranchial, while differing from its fellows in neither size nor shape, ends abruptly with no hint of ligamentous or other continuations.

The distal extremities of the connecting ligaments are connected with the four epibranchials, all of which are slender and rod-like. The first curves slightly forward and ends in a separate short, straight pharyngo-branchial. This element in turn is succeeded by a short but distinct suspensory pharyngeal which lies just below and at one side of the unossified first vertebra. Anteriorly it articulates

loosely with the exoccipital. The third epibranchial shows a slightly curved hook on the posterior side near the upper end, perhaps a disappearing remnant of a former bifurcation. The upper end articulates closely with a pharyngo-branchial of bizarre shape. From the point of articulation a long narrow rod extends upward and anteriorly, articulating with the second pharyngo-branchial. From the ventral surface of the third pharyngo-branchial, close in front of the articulation of the epibranchial, are two to four sharp teeth. Posteriorly the pharyngo-branchial expands into a wide plate and from the lower, posterior angle of this area a small separate ossification gives rise to a cluster of four or five large, downwardly projecting teeth. The fourth epibranchial shows no attachment to a pharyngo-branchial and its bifurcation takes the place of two oppositely directed arms, giving to the whole a shape like a slender tack hammer.

Adult female pectoral girdle: (Fig. 70). Correlated with the total absence of pectoral fins in the adult is a simplified pectoral girdle. The post-temporal is a slender rod of bone slightly bent at its upper end, the whole sloping obliquely forward. It is widely displaced from normal connection with the epiotic, its center lying at the vertical of the articulation between the second and third ossified vertebrae. The distance of this posterior dislocation from its normal point of attachment is almost equal to the length of the entire skull. Below it, and not closely attached, we find the upper end of the supracleithrum which extends in a downward curve to about three times the length of the post-temporal. Close behind its upper head arises the closely welded cleithrum which increases in size in the course of its downward curve until it ends in a forwardly directed knob, its total length being almost twice that of the supracleithrum.

Adult female pelvic girdle: The pelvic girdle consists of a pair of small, triangular, moderately well ossified bones far separated from each other. They lie immediately above the firmly ossified rays of the pelvic fin.

Adult female vertical fins and baseosts: (Fig. 73). The dorsal and anal finrays are all well ossified. The anterior margin of the expanded base of each is prolonged into the pair of short, external spines characteristic of the genus, while there is an exactly similar pair arising from the posterior edge of the base, oppositely directed and

imbedded in the skin. This reinforced base is notched longitudinally and hinges loosely upon one side of a triangular, leaf-like bit of bone. The latter is attached by its opposite angle to the middle of a strong, rod-like baseost which is placed horizontally close beneath the skin. Each baseost touches its neighbors and shows no connection, either direct or indirect, with the vertebral column, while the succession of baseosts and finrays is quite independent of the vertebrae. Hence a continuous supportive rod is formed along the base of each fin which, in the early stages of growth and while still cartilaginous, must serve by the extension of its elements as a plough of sorts, boring forward through the flesh, heading the great anterior migration of the dorsal and anal rays. The triangular, central projections are minute anteriorly, but toward the posterior parts of the fins they become much enlarged and the baseosts are correspondingly more deeply sunken in the flesh. As has been previously explained, the most posterior of the finrays remain crowded together in the same positions as in the larvae; as is to be expected, their underlying baseosts are much shorter than the rest.

Adult female vertebral column: The entire vertebral column and its appendages are well ossified with the exception of the first vertebra. Counting this element and the urostyle there are 78 vertebrae.

As in the young fish the centra are all biconcave and completely lack zygopophyses. Their adult character is manifested in their proportions: all except a few at the beginning and end of the column are considerably greater in length than in maximum diameter, and are much narrowed medially, so that in shape they resemble elongated hour glasses. This distinctive adult shape is exaggerated in direct proportion to the length of the fish (Fig. 61D, E). The most anterior vertebrae are small and relatively deep (2.4 mm long, by 1.6 mm maximum diameter, by .9 mm minimum diameter, in the 267 mm specimen from Bermuda). The maximum size is reached at about the origin of the dorsal fin (4.6 mm by 2.2 mm by .75 mm). This size is maintained until the level of the ninth or tenth anal rays is reached, where the elements become gradually smaller, the last centrum before the urostyle measuring only .6 mm by .4 mm by .16 mm.

The unossified first vertebra (Fig. 71) has no appendages whatever. It is capable of considerable extension antero-posteriorly and its dorsal and ventral halves can expand and contract alternately, so

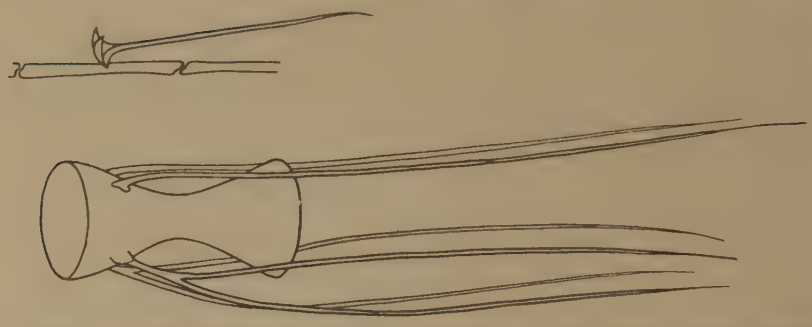


Fig. 73. Tenth dorsal ray, baseost and vertebra from adult female, standard length 267 mm

that the element actually functions at once as neck and muscle. This makes possible both an up and down movement of the head and a forward thrust, which must increase tremendously the efficiency of the jaws in seizing prey. When we add to the 90 degrees drop of the lower jaw an upward lift of the upper jaw and cranium to an equal extent, the ingestive ability of this genus is seen to be about one hundred per cent.

The second, third and fourth vertebrae, although the centra are somewhat juvenile in size and shape, are firmly ossified. On the anterior dorsal region of each is a pair of well developed neuropophyses having stout neural spines, the latter becoming reduced in size posteriorly. There is no tendency toward fusion to form neural arches. From the base of each neuropophysis arises a long and slender epineural, a little longer than the centrum. Finally, from close to the ventral mid-line of each centrum is a pair of feebly developed parapophyses, each giving rise to a rib, scarcely differentiable from its parapophysis and longer than the epineurals.

Beginning with the fifth element (the fourth ossified vertebra) the neural spine disappears, except for an occasional reappearance as a minute knob, until the several neural arches are formed, far back close to the caudal base. In the absence of the neural spines, the neuropophyses become as slender as the epineurals to which they still give rise (Fig. 73). These backwardly directed structures are now relatively much longer than in the anterior part of the column, being over 2.5 times as long as the centra. Beneath the posterior part of the dorsal fin, however, the neuropophyses become enlarged, while the epineurals are reduced and finally lost with the formation

of the neural arches and their attendant specializations at the end of the fin.

Also beginning with the fifth vertebra long epipleurals, identical in length and diameter with the ribs, arise at the very base of the latter; these two ventral elements do not increase in length to the same extent as the epineurals, being now somewhat shorter than the latter. Like them they conform to the slenderness of the body by curving almost horizontally backwards. The parapophyses increase in size after the tenth anal ray, developing central foramens and a short spine anterior to the ribs and epipleurals. Both of the latter elements gradually shorten, the epipleurals dying out at the fourteenth vertebra before the last, and the ribs at about the tenth, although vestiges remain attached to the specialized parapophyses of the more posterior vertebrae. Corresponding to the lack of neural arches and spines throughout most of the length of the column, haemal arches are formed only behind the end of the anal fin (see below).

Adult female—the posterior part of the vertebral column and the caudal fin: (Fig. 74). Usually the first vertebra to show caudal specialization is the 72nd or sixth anterior to the urostyle segment. This centrum shows a noticeable decrease in length (1.67 mm as compared with 1.88 mm of the two preceding centra), as well as the first appearance of a neural arch with a single, strong, median neural spine. Posterior to the triangular neural arch there is a similar bony structure which extends from the base to the tip of the arch. It is fused with the left base and the tip of the neural arch. Between the upper two-thirds of the structure there is a clear unossified area. This is the only dorsal appearance of such a double structure in the posterior half of the body. It could easily be passed by as an abnormality or as evidence of a pseudo-double vertebra, but this extra support and strengthening appears where it is most needed in a gap free of fin rays midway between the last posterior dorsal ray and the first anterior caudal raylet. There is also an anterior median projection from the dorsal side of the neural spine.

There are two separate haemal bases, each with irregular narrow spines. The left one extends posteriorly to the haemal process of the following centrum while the right one extends only midway. A narrow ridge of bone with several teeth-like serrations extends the full length of the haemal base. At the distal end this broadens into

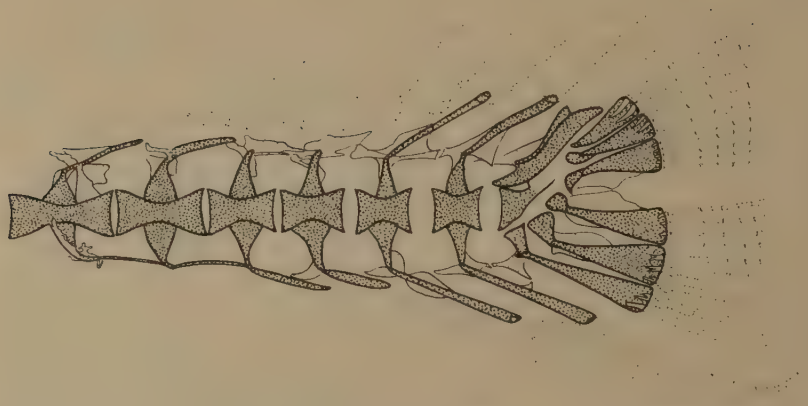


Fig. 74. Posterior vertebral column and base of caudal fin in adult female. (× 8.5).

two prong-like projections, one directed dorsally and the other ventrally.

The centrum of the 73rd, or the fifth vertebral process anterior to the urostyle, is situated directly below the first caudal raylet. The general form is similar to the 72nd. The centrum is shorter (1.34 mm) than the preceding but the depth is the same (.75 mm at the articulating edge and .32 at the center). The neural base is a little longer and has small median anterior and posterior projections at its distal end and a short prong which divides into two lateral barbs. The strong neural spine extends backward to the anterior projection of the following process.

The haemal process of the 73rd vertebra is very like the preceding but greatly simplified with only a hint of extraneous structures and almost symmetrically paired spines that extend to and touch the tip of the next posterior haemal process. The 74th and 75th vertebrae are alike in every way but details. The posterior centrum is shorter than the preceding, the 74th being 1.08 mm and the 73rd .91 mm long. The neural spines of both have developed into broad flat bones that occupy most of the area between the ray bases and the tip of the neural arch. There are anterior and posterior projections from the spines which extend as far as similar projections from adjacent structures. The haemal spines have become strong and dagger-like and each touches the anteriorly directed basal

projections of the next posterior spine. The first haemal arch appears in the 74th process.

The 76th and 77th vertebrae are almost identical part for part, dorsal and ventral. The lengths of the centra (.81 mm) are the same. The distances between the centra become wider as we approach the urostyle.

Prolonged neural and haemal spines appear for the first time in the 76th and 77th vertebrae. These extend into the caudal contour and form a definite part of this structure. Each spine is a strong, long, flat bone, which becomes gradually broader at the distal end.

The urostyle is ossified only in the anterior part which resembles an unspecialized half centrum. The upturned posterior end has only a fragmentary patch of bone scattered over the dorsal and ventral surfaces as far as the position of the third hypural. No separate segments can be detected in the clear, unossified, tapering end of the urostyle. This is a distinct contrast to the urostyle development in some of the shallow-water Isospondylids where ossification is dense and several separate segments are prominent in the upturned end.

The entire dorsal surface of the urostyle is covered by a broad, saddle-shaped neural structure that extends posteriorly into the caudal contour. There is one well defined epural that extends along the dorsal surface of this bone. At its proximal end it appears to be imbedded in the neural structure that covers the urostyle.

There are six hypurals, three dorsal and three ventral to the median axis. These bones are elongate, flattened, and triangular. The first hypural on the ventral surface is the longest and the second is the broadest of the six. Both the arch and the prolonged spinal part of each hypural becomes shorter in each successive dorsal bone. The remains of the haemal arch of the sixth hypural on the dorsal surface is rudimentary. None of the arches are attached directly by ossified structure to the urostyle. There is a clear unossified area between the arches and the urostyle. The distal ends of the three dorsal and the three ventral hypurals broaden out and form two almost solid fan-like units. The wide gap between the dorsal and ventral units is partly solidified by two, thin, median wings of bone. Attached to and extending between the tips of the two central hypurals is a prominent ligamentous band.

In the external and internal characters the ventral half of the

caudal fin is more developed than the dorsal half. The longest ventral rays extend three millimeters or more beyond the dorsal rays and are stouter and more heavily ossified. The ventral hypurals are longer and heavier than the dorsal hypurals.

The sequence of raylets and rays, counting from the anterior dorsal around to the ventral is 14 + 10 + 10 + 7 = 24/17. The first dorsal and ventral rays are rudimentary and entirely embedded in the tissues, and in uncleared specimens both are invisible. The first anterior dorsal ray and the first and second anterior ventral rays are only slightly more developed than the raylets that immediately precede them, but the rays possess the character that distinguishes them from raylets, that of cross bars.

There are four strongly ossified ventral rays, the third, fourth, fifth and sixth—the last three of which are bifid for the posterior half of their length.

The first ventral ray has a single cross bar near its tip which is in line with the first bar at the basal end of the second ray. This has six bars commencing half way between the base and the tip. The second ray is a little broader and twice the length of the first and more heavily stained than any of the preceding rays or raylets. Posterior to the third bar the ray becomes thread-like and diminishes to less than half the width at its basal end.

The first and second ventral rays are attached to the second, or last, prolonged haemal spine which forms part of the caudal contour.

There are three strongly ossified and elongated dorsal rays, the second, third and fourth. In size none are as stout as the corresponding ventral rays. The first anterior dorsal ray is twice the length of the preceding raylet, half the length of the following, or second ray, and has three or four cross bars.

Adult Female Digestive System: (Figs. 62F, 75). The alimentary canal measures 56 per cent of the standard length, slightly more than in the transitional adolescent. This relative increase in length is caused principally by the elongation of the oesophagus, which in turn is due to the reduced size of the head. The black stomach is short compared with its size in many Stomiatoids, such as *Stomias* and the more elongate Melanostomiatids. It is contained 6.1 times in the standard length and ends just short of the plane of the pelvic fins. The two caeca are well developed, the more posterior being the larger and about equal in length to the pyloric canal joining stomach

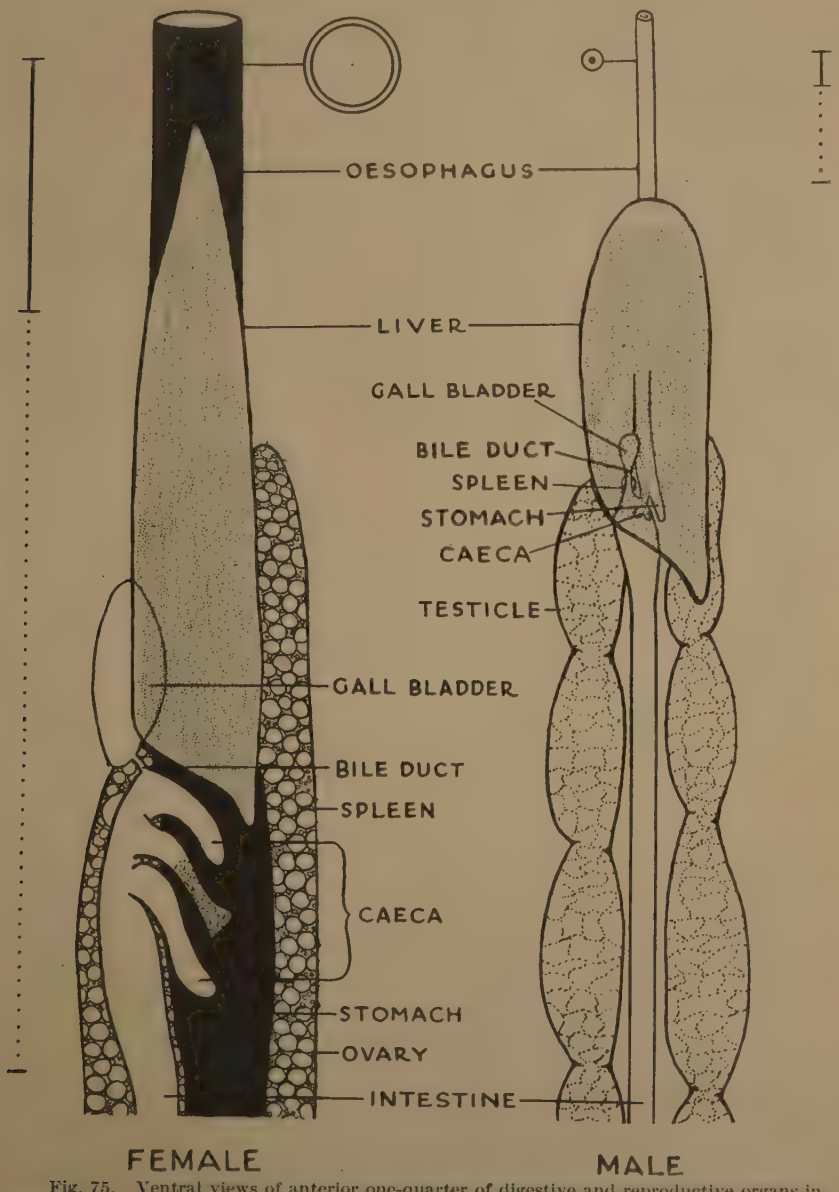


Fig. 75. Ventral views of anterior one-quarter of digestive and reproductive organs in breeding adults. Left, female, standard length 267 mm; right, male, standard length 35 mm. The relative length of the alimentary canal in the two specimens is shown by the straight lines, the portion figured being solid, the remainder broken.

and intestine. The liver is single-lobed and almost as long as the oesophagus, relatively much longer than in any preceding stage. It broadens slowly from its anterior point beneath the oesophagus until the posterior portion extends upwards around the oesophagus and completely surrounds it. The left side of its terminal edge is drawn out into an attenuated tip. The pancreas is a thin layer of tissue lying between the anterior half of the liver and the oesophagus, scarcely distinguishable in the preserved specimen from the substance of the liver. The deflated gall bladder is almost a third as long as the liver, lying above that organ's posterior right end. The bile duct is even shorter than in the transitional adolescent, the bladder being very close to the pyloric region. The spleen lies above and behind the posterior end of the bile duct. The intestine is perfectly straight and smaller in diameter than the oesophagus.

The following measurements were taken: Length of alimentary canal 150 mm; oesophagus length 30 mm; oesophagus breadth 3 mm; stomach length 44 mm; longest caecum 5 mm; maximum liver length 25 mm.

Adult Female Reproductory System: (Fig. 75). The left ovary begins 13 mm behind the mandibular angle; it is 135 mm long with a maximum breadth of 4 mm and a maximum thickness of 2 mm. The right is similar except that it originates 9 mm behind the left. Both are broadest toward the middle of their lengths, tapering gradually anteriorily and posteriorly to rounded ends. The eggs have been already described.

Adult Male Trawling Data: The external characters are based upon the following specimen: Department of Tropical Research No. 16,645; Bermuda Oceanographic Expeditions of the New York Zoological Society; Net 770; July 4, 1930; 12 miles south of Nonsuch Island, Bermuda; 700 fathoms; Standard length 38 mm.

Adult Male Measurements and Counts: Total length 41.6 mm; standard length 38 mm; depth, maximum, at dorsal origin, 1.9 (in length 20); depth, minimum, behind anal end, 1.1 (in length 34.6); head 3.9 (in length 9.7); eye 1.1 (in head 3.6, in length 34.6); snout 1.1 (in head 3.6, in length 34.6); dorsal origin to caudal base 24 (in length 1.6); anal origin to caudal base 11 (in length 3.5); dorsal rays 62; anal rays ca. 40; caudal rays XII + 10 + 9 + VII; postorbital 1.4 (in head 2.8, in length 27.1); serial photophores: branchiostegal organs 13; lateral series 49 (last 4 above anal); ventral series, I–A 58 (last 5 above anal), A–C 20; penis 1.3 (in eye .8).

Adult Male External Characters: (Figs. 47; 50F; 57A, B; 66). In many ways this adult fish is a typical post-larva: The general color is dark brown, not brownish black as in the adult female. The greatest depth is toward the middle of the body, not at the shoulder, and the caudal peduncle is relatively deeper than in the female. The head is more than a third longer in proportion to the length than in adult females, while the eye, although perfectly round, firmly fixed in the socket and having no trace of stalk, is between one-third and one-half again as large as the eyes of adult females. The snout also is somewhat longer and exceedingly convex, while the female snout tends to concavity. The lower jaw is strongly curved and projects noticeably beyond the upper. The premaxillary is relatively no longer than in the larva, although it has the upward anterior projection typical of this group of fish; the maxillary, although showing an increase in length in the male since transitional adolescence is noticeably shorter relatively than in the female. Both upper and lower jaws are completely edentulous.

The pectoral nubbin has entirely vanished and there is no sign whatever of pelvic fins. The dorsal and anal rays fall within the range of the adult female counts, but are soft and relatively close together; the typical inter-ray spines of *Idiacanthus* are present. The shape of the caudal fin is the same as in the female, and the numbers of elements identical, but the fin is contained 10.6 times in the standard length instead of about 33.3—that is, the fin is relatively more than three times as long as in the female, a character normally indicating immaturity throughout this group.

The enormous cheek light is much longer than the eye; a narrow subocular portion, evidently fused with the antorbital, extends flush with the anterior border of the eye; behind the eye the organ is enormously swollen, bounded dorsally by the horizontal though the middle of the eye and ventrally by the maxillary. Its maximum length is 1.4 mm, while the theoretical maximum depth to which it might be opened is .7 mm. In this and all of the other adult male specimens in the collection, however, the luminous center is never more than half exposed, always directed downwards. There is no trace of a barbel. The serial photophores are well developed, violet in the fresh specimen. There are, however, two or three organs fewer in the lateral series than in the minimum counts for adult females, exactly as is common among post-larvae.

Corresponding to the luminous material at the bases of the teeth in the adult female, there is a complete line of luminescence within each of the transparent jaw bones of the male. This is especially noticeable in the mandible. There is no luminous line beneath the postorbital light, since the latter organ is pressed against the maxillary. On the body a double series of luminous patches alternates with the photophores as in the female, the lower row being the stronger. There is an immense quantity of luminous granular matter in the webbing of the dorsal and anal fins, along their bases and on the caudal fin. The caudal luminous organs are essentially the same as in the female, except that the dorsal, peduncular organ is scarcely differentiated from the luminous matter between the dorsal caudal raylets, while the finger-like process of the organ of the lower caudal lobe is rudimentary.

There are no lesser light organs on head or body.

Adult Male Osteology: The adult male is extremely difficult to characterize with any exactitude. Some of the osteological elements cannot be distinguished from those of the adult female, while others show various degrees of interrupted development and some are almost wholly larvoid.

The degree of ossification, while very slight at the best, varies so greatly that no two males show it to the same extent. Of half a dozen specimens subjected to the clearing and staining process only three absorbed any stain whatever, and in these it was confined entirely to the jaw apparatus and its supports, to the region of the intromittent organ, and to the caudal fin. The particular areas of ossification in these specimens, listed in order of intensity of stain, are as follows: Mandibular symphysis; premaxillary; maxillary, mandible; first anal rays; base of caudal rays (in two out of three cases); parasphenoid; preopercle; cleithrum; junction of opercle and hyomandibular; upper part of hyomandibular; pharyngeals; pterotics and epiotics; vertebrae in central third of body. In the last three or four areas mentioned the stain is always exceedingly light.

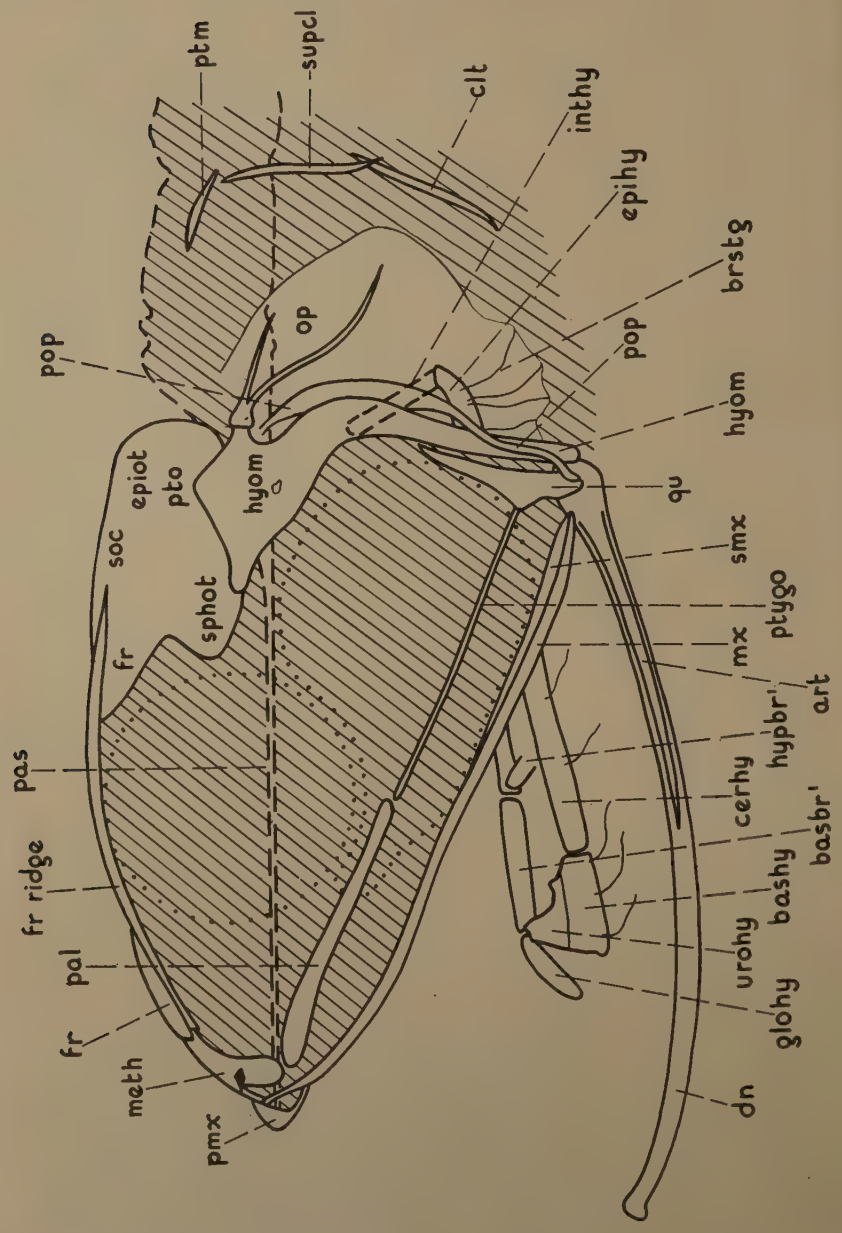
This variation in the amount of bony tissue indicates either that the full breeding condition in this sex is assumed at different stages of development in various individuals, or else that such characters as the degree of ossification continue development after the fully adult condition is reached.

The general conformation of the bones in all adult males is, however, very similar in all specimens.

Adult male skull: The cranium viewed from above differs only slightly from that of the adult female. It is especially interesting that the limits of the various bones are even less distinct than in the full-grown female. The chief distinction is the rudimentary condition of the frontal ridges and mucous tunnels. Whatever function these subserve in the adult female, they are apparently useless in the opposite sex.

Adult male palato-pterygoid arcade: (Fig. 76). The hyomandibular is much more generalized and less definite in shape than in the female. The three expanses of the head of the bone are little more than blunt protuberances with, of course, perfect articulation with the pterotic and the main ossification of the opercular. The elongated body of the hyomandibular shows a very striking immature stage in the general direction of the suspension of the jaw. Instead of continuing straight backward almost paralleling the pterygoid as in the adult female, it describes a nearly right-angled curve downward and forward to its articulation with the angle of the jaw. The quadrate is relatively smaller in this sex and is not closely applied to the hyomandibular, but follows its upward and backward direction lying at right angles to instead of paralleling the pterygoid. The obliteration of the internal flange of the head of the hyomandibular together with the great circle described by its body and the quadrate not only reflects a decided larvoid character but also permits of a large free area at the side of the head, even larger than the eye socket itself, which houses the huge light organ of the male. Therefore this same curve of the hyomandibular reflects at one time very primitive and very specialized conditions. No trace of the metapterygoid is visible, its obliteration being a further adaptation in making room for the cheek light. The secondary upper jaw is not very unlike that of the adult female except that the palatine is almost equal to the pterygoid in length and while stouter throughout lacks the anterior dilation.

Adult male jaw apparatus: (Fig. 76). In the upper jaw we have conditions almost wholly larval, the premaxillary being very small, for although it has the upwardly directed, bony cone found in the adult female, laterally it hardly reaches farther than the head of the palatine. As in the larva the entire profile of the edge of the upper jaw is formed by a slender, undulating maxillary with the typical supramaxillary in place. The lower jaw, an evenly curved, slender


ptm
supcl
clt
inthy
epihy
brstg
pop
op
pop
hyom
epiot
pto
hyom
qu
soc
smx
sphot
mx
ptygo
fr
art
pas
hypbr'
cerhy
basbr'
fr ridge
bashy
pal
urohy
fr
glohy
meth
dn
pmx

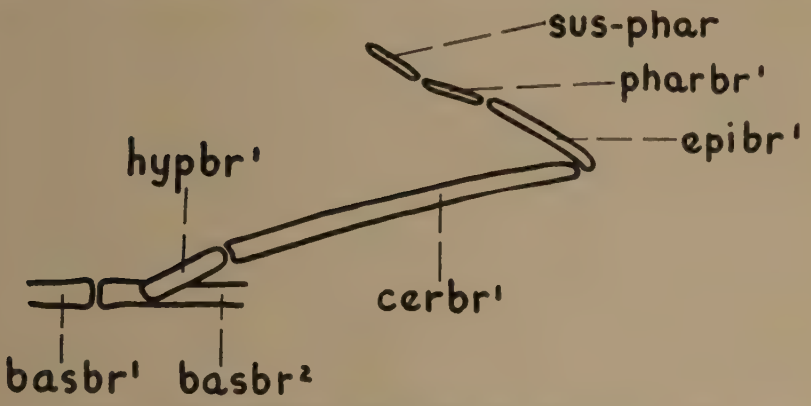


Fig. 76. (Left) Elements of head of adult male, lateral view. (× 28).
Fig. 77. (Above) First branchial arch of adult male.

rod, projects conspicuously beyond the premaxillary. The articular is normal in position and extent. In the most ossified individuals the anterior halves of both jaws show strong deposits of bone, gradually lessening posteriorly. The jaws and the entire oral cavity are completely edentulous.

Adult male opercular bones: (Fig. 76). Three elements only are recognizable in this assemblage. The opercle itself is supported as in the adult female by two centralized ridges and by the preopercle. The latter follows the general outline of the hyomandibular but, as in very young specimens, is unattached to that bone and very slender and sinuous ventrally. The posterior branchiostegal rays are long and strong and continue the webbed outline of the opercle.

Adult male hyoid arch: (Fig. 76). In the hyoid arch the elements are far less specialized in shape than in the adult female. The glossohyal is relatively larger and thicker, the urohyal smaller, while the posterior branchiostegal rays are more scattered than in the adult female.

Adult male branchial apparatus: (Fig. 77). The branchial arches are exceedingly primitive and absolutely lack the specialized extensory power seen in the corresponding structures of the adult female. There is no hint of the extremely elastic ligaments between the articulations of the ceratobranchials and epibranchials, while the three superior elements, the epibranchials, pharyngo-branchials and the suspensory pharyngeal, are all very short, cartilaginous rods with

no hint of the elongate characters of the adult female. And so, correlated with the edentulous jaws, we find the branchial arches wholly lacking in the power to stretch wide apart and so admit passage for food of any size.

Adult male pectoral arch: (Fig. 76). The post-temporal, like that of the adult female, is widely separated from the epiotics. The supracleithrum and cleithrum are very distinct, overlapping only at their extreme tips in a manner quite different from the close association of these bones in the adult of the opposite sex. There is no trace of either pelvic girdle or pelvic rays.

Adult male vertical fins and baseosts: Only the anterior half of the anal fin is ever ossified. Its specialized first rays are subsequently described in connection with the reproductive system. They alone have their bases simple and almost unexpanded, the remaining dorsal and anal rays each having two pairs of basal spines—one external and one internal—exactly as in the female. In both fins the baseosts, so strongly developed in the female, are visible only as slivers of cartilaginous tissue, although longitudinally placed as in the opposite sex.

Adult male vertebral column: The vertebral column is not completely segmented. Differentiation of the vertebrae is only indicated in the opercular region and apparently occurs in the extreme posterior caudal area last.

The only trace of ossification in the column in any of the specimens occurs, in approximately the center third of the body, ending at about the level of the intromittent organ. Here there is a light deposit on the dorsal and ventral, and along the articulating surfaces, of the centra.

The centra (Fig. 61d) are not elongated and spool-shaped as in the adult female, but instead the dorsal-ventral depth is greater than the length, and the shape, viewed laterally, is rectangular. The dorsal and ventral surfaces in the midportion of the body are even slightly convex, so that the centra of the adult male may be said to be actually more larvoid than those of the larvae themselves. This is largely explained by the shrinkage in the length of the fish which takes place during adolescence. A centrum, toward the middle of the body of a specimen 32 mm in length is .59 mm long and .82 mm in maximum diameter.

The vertebral appendages, although completely unossified and

comparatively short, are exactly similar to those of the female in form and relative positions.

Adult male end of vertebral column and caudal fin: (Fig. 78). As in the adult female, distinct caudal specialization occurs in the area of the sixth and fifth vertebrae anterior to the upturned urostyle. Here, the neural and haemal processes become heavier, longer and directed more posteriorly. Unlike the adult female, all the processes in the male are simple and rod-like. None show bone deposit. The two posterior neural and haemal spines are enlarged and prolonged and are the first to form a definite part of the posterior caudal contour.

Only the anterior part of the specialized neural structure, so prominent in the female along the dorsal surface of the urostyle, can be determined. The single epural is present and occupies some of the area between the urostyle and the last prolonged neural spine.

There are six hypurals, generalized in shape and lacking all extraneous structures. Only in the first hypural is the haemal arch defined. The distal ends of the three dorsal hypurals form a solid unit for the last fourth of their length. In a 42 mm specimen the ventral hypurals, as well as the dorsal, are fused distally.

The sequence of raylets and rays, counting from the anterior dorsal element is typically $11 + 10 + 11 + 5 = 21/16$. Slight ossification is shown at the bases of the rays in two of the specimens.

Adult Male Digestive System: (Figs. 63F, 65F, 75). As in the male adolescent and transitional adolescent, the gut of the adult is three-fifths as long as the fish or relatively almost equal to that of the adult female. In the male, however, all portions of the digestive system are, with the exception of the liver, degenerated to varying degrees. The oesophagus is very narrow with a thread-like bore and is shorter than before, as the liver, although no longer, now completely overlaps the pyloric organs ventrally; the stomach is the same minute, white appendage found in earlier stages; the caeca are rudimentary and no distinct pyloric canal is developed; the gall bladder and bile duct are both much reduced; and the intestine is only slightly broader than the oesophagus. The liver is no longer than in younger specimens, but it is broader, completely surrounding the oesophagus with the edges of the lobe meeting dorsally. As in the female the pancreas is an inconspicuous layer of tissue between the anterior half of the liver and the ventral side of the

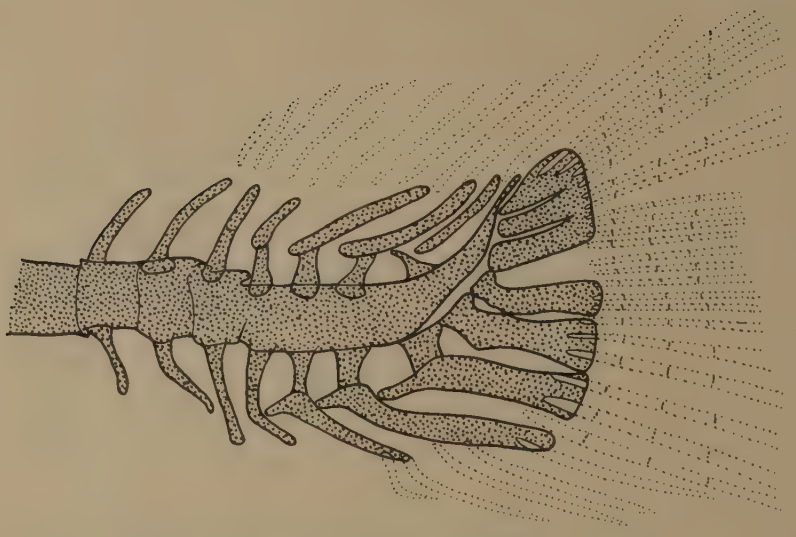


Fig. 78. Posterior vertebral column and base of caudal fin in adult male. (× 34).

oesophagus. The spleen is slightly reduced. Compared with the transitional adolescent male the reductions of the diameter of the gut and of the size of the gall bladder are the greatest changes. The only developmental reduction held in common with the female is the shortening of the bile duct. Pigment is lacking from the male coelom with the exception of a small and variable quantity on the oesophagus. Its most constant form is an elongate, broken patch about half the length of the oesophagus on its anterior dorsal surface.

The posterior end of the intestine passes close to the sperm duct, but is quite separate from it. The anal papilla appears as an anterior swelling at the base of the intromittent organ.

Adult males vary somewhat in the size of stomach, caeca and gall bladder, all of these organs being almost non-existant in several of the specimens examined. The following measurements show typical proportions and were made upon a male 32 mm in length, in full breeding condition: Gut length 19.3 mm; oesophagus length 2.1; oesophagus breadth .11; stomach length .34; stomach breadth .06; caecum .15; liver length 1.8; gall bladder length .17; diameter of intestine, anterior portion, .13; diameter of intestine, posterior portion, .08.

Adult Male Reproductive System: (Figs. 75, 79). The testicles are relatively as long as the ovaries of the female, the longer (left side) beginning at a point about one-tenth of the distance from throat to anus. In the male this falls slightly behind the middle of the liver. Both right and left organs extend clear to the end of the body cavity. In section the testicles are circular with maximum diameters three times or more that of the intestine. Each organ is divided into at least fourteen or fifteen unequal divisions by constrictions and small, single pleats. These vary in position and sometimes in number and distinctness on the two sides of the same fish. The testicles are entirely covered by a continuous network of pigmented strands, the fundamental pattern of which consists of transverse bands connected by longitudinal cross-bars. The following measurements were made upon the 32 mm male mentioned above: Left testicle length 17 mm; maximum diameter .38; minimum diameter (excluding constrictions) .26.

Immediately anterior to the vertical from the anus both testicles converge to form a common sperm reservoir which extends dorsally close to the vertebrae and posteriorly to the vertical from the seventh anal ray. From the ventral side of this reservoir, a little before the middle of its length, a broad duct leads down through the intromittent organ, ending in a pore at the anterior side of its swollen tip.

The intromittent organ is about equal in length to the diameter of the eye, dark brown in color, and extending diagonally downwards and backwards against the first anal rays. The latter are very definitely modified for its support: The first ray is always flattened throughout its length with a triangular expansion at each side along its upper and median portions. This ray is sometimes highly ossified, as are the several subsequent rays, although less strongly. The second and third rays usually pass to the right of the intromittent organ and have their distal portions securely attached to the posterior side of its tip, while the fourth and fifth rays similarly support the left side. The sixth ray is linked closely to the group by webbing. The positions of the individual rays vary somewhat on different specimens, but the general plan is always the same. There is no trace of basal spines in connection with any of these modified rays. Due to the intimate connections between rays and intromittent organ and the consequent limited movement of the latter, its func-

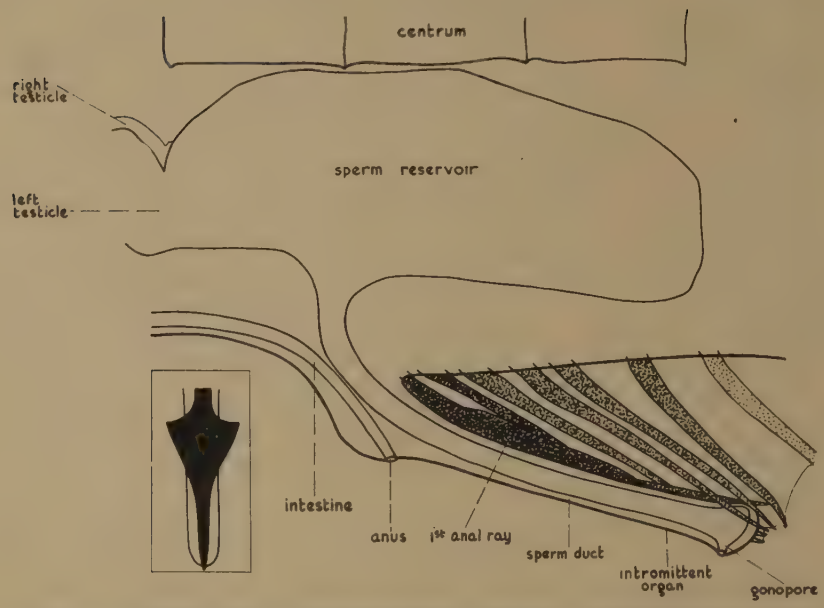


Fig. 79. Sagittal section through intromittent organ and surrounding region of adult male. The shaded areas indicate various degrees of ossification in the anal rays. (× 60). Inset: posterior view of first anal ray and intromittent organ.

tioning as a penis during any sort of internal fertilization seems very questionable. This organ is analogous but not homologous with those found in many fresh-water oviparous fish.

Beginning with the seventh, the rays are slightly or not at all ossified.

Ecology

Vertical and Seasonal Distribution: The vertical, monthly and yearly distribution of the Bermuda specimens of *Idiacanthus fasciola* is shown in Fig. 80. Two nets, drawn in September at 100 fathoms, contained eleven of the thirteen larvae in the collection. The rest of the fish, at all stages of development, were caught between 500 and 1000 fathoms, at a mean depth of 681 fathoms. The diagram at the right of the map (Fig. 48) indicates this distribution in graphic form. As in the case of numerous other genera of deep-sea fish taken by the Bermuda expeditions, *Idiacanthus* (except larvae) was never caught off Bermuda at the comparatively

shallow depths from which it has been often reported in other parts of the world. From the Bathysphere I saw an adult female at 200 fathoms (Beebe, 1930, p. 222).

The accompanying diagrams (Fig. 81) indicate the seasonal distribution of the species, divided into groups according to age and sex, throughout the major portion of the three-year trawling season. (Too few deep-sea nets were drawn in April and October to furnish comparable data for these months, and during the winter it has so far been impossible to do any trawling whatever.) The upper chart shows the actual numbers of individuals taken; in the lower are the numbers that theoretically would have been taken had as many nets been drawn every month as during September.[1] But in both charts the proportionate sizes of the various groups are in general the same: Through the months adult males formed the most numerous class and were distributed fairly evenly during the period. They were, however, most plentiful in the summer months, and adult females and larvae were taken only in August and September. Young specimens of both sexes were less numerous than the adult males, but were similarly scattered through the season; their month of maximum concentration, however, as with the larvae, was September. From this it may be inferred that there is a chief breeding season in late summer.

SOCIABILITY: The larvae undoubtedly school, as shown by the occurrence of the youngest stages in groups of three and eight individuals, respectively. Also, two post-larval males were taken together and, in another case, a post-larval female with an adolescent of the same sex. In each of five other nets adult males were taken two at a time. The latter cases may have been accidental, as it seems likely were the six other pairs of fish of very dissimilar growth stage: in each of the latter the pair consisted of a post-larva or transitional post-larva of either sex caught with a transitional adolescent or adult female. The one breeding female came up with a male post-larva. No evidence was found on adults of either sex of parasitic habits in the male.

ABUNDANCE: *Idiacanthus fasciola* is fairly common among the deep-sea fishes taken off Bermuda. One or more specimens occurred in nine per cent of all of the nets drawn between 100 and 1000 fathoms, the limits of its vertical distribution in this locality.

[1] See Zoologica, Vol. XVI, No. 1, p. 7.

Fathoms	April			May			June			July			Aug			Sept			Oct			Total		
	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931	1929	1930	1931
100																		11						11
																		11						11
200																								
300																								
400																								
500	2						2		1		2				2		3	2				4	5	5
	2						3				2				2		5					14		
600	3				1		3		1	1	3	1	2		6	2	5	6			2	11	9	16
	3				1		4			5			8			13			2			36		
700	1			4	3		5	3	3	3	6		1		1	5	4	2				19	16	6
	1			7			11			9			2			11						41		
800	1			1			1			3	1		1		1	4	2					11	3	1
	1			1			1			4			2			6						15		
900				1			1						2		1			3				4		4
				1			1						3			3						8		
1000							1								2		1					1	1	2
							1						2			1						4		
Total	7			6	4		13	3	5	7	12	1	6		13	11	15	24			2	50	34	45
	7			10			21			20			19			50			2			129		

Fig. 80. *Idiacanthus fasciola* Peters. The vertical, monthly and yearly distribution of the specimens taken by the Bermuda Oceanographic Expeditions.

FOOD: The stomachs of ten of the largest females, all transitional adolescents and adults, were examined, and of these three contained remains of fishes. One only was recognizable, a *Diaphus* sp., measuring about 61 mm in length and taken from an *Idiacanthus* of 255 mm. In the intestines of all of the specimens there was a smaller or larger amount of unrecognizable material.

The intestines of several larvae and post-larvae of both sexes contained diatoms and the remains of minute crustacea. Brauer[1] also found crustacea in his specimens of *Stylophthalmus*.

Due to the degeneration of the digestive system all males subsequent to the post-larval stage have the alimentary tract entirely empty.

ENEMIES: *Idiacanthus fasciola* has not yet been found in the stomach of any creature, nor have parasites been observed. It is of interest to note, however, that the type of *I. niger* and one other

[1] Brauer 1906, p. 68.

	MAY	JUNE	JULY	AUGUST	SEPTEMBER
LARVAE				○	○○○○○○○○○○ ○○
IMMATURE FEMALES		♀♀♀♀♀♀	♀♀♀♀♀	♀♀♀♀	♀♀♀♀♀♀♀♀♀♀ ♀♀♀
IMMATURE MALES	♂♂♂	♂♂♂	♂	♂♂♂♂	♂♂♂♂♂♂♂♂♂♂ ♂♂♂♂
ADULT FEMALES				♀♀	♀♀
ADULT MALES	♂♂♂♂♂♂♂	♂♂♂♂♂♂♂♂♂♂ ♂♂	♂♂♂♂♂♂♂♂♂♂ ♂♂♂♂	♂♂♂♂♂♂♂♂	♂♂♂♂♂♂♂♂♂

	MAY	JUNE	JULY	AUGUST	SEPTEMBER
LARVAE				○○	○○○○○○○○○○ ○○
IMMATURE FEMALES		♀♀♀♀♀♀♀♀	♀♀♀♀♀♀♀♀	♀♀♀♀♀♀♀	♀♀♀♀♀♀♀♀♀♀ ♀♀♀
IMMATURE MALES	♂♂♂♂♂♂	♂♂♂♂	♂♂	♂♂♂♂♂♂♂	♂♂♂♂♂♂♂♂♂♂ ♂♂♂♂
ADULT FEMALES				♀♀♀♀	♀♀
ADULT MALES	♂♂♂♂♂♂♂♂♂♂ ♂♂♂	♂♂♂♂♂♂♂♂♂♂ ♂♂♂♂♂♂♂♂	♂♂♂♂♂♂♂♂♂♂ ♂♂♂♂♂♂♂♂♂♂	♂♂♂♂♂♂♂♂♂♂ ♂♂♂♂	♂♂♂♂♂♂♂♂♂

Fig. 81. Diagrams indicating the seasonal distribution of the growth stages of *Idiacanthus fasciola* off Bermuda, throughout the major portion of the three-year trawling season. The upper chart shows the actual numbers of individuals taken; the lower, the numbers that theoretically would have been taken had as many nets been drawn every month as during September. (See Zoologica, Vol. XVI, no. 1, p. 7).

specimen of that species were taken off New Zealand in the stomachs of gropers (*Polyprion oxygeneios* and *Polyprion americanus*)[1]

Study Material

The following list gives the catalogue number, net, depth in fathoms, date, length and growth stage of each specimen of *Idiacanthus fasciola* taken by the Bermuda Oceanographic Expeditions. All were caught in the cylinder of water off the Bermuda coast described on page 5 of the present volume (Vol. XVI, No. 1).

No. 8,733; Net 6; 600 F.; April 5, 1929; 129 mm. Trans. Adol. ♀
No. 8,760; Net 15; 500 F.; April 12, 1929; 35 mm; Adult ♂
No. 8,820; Net 23; 600 F.; April 15, 1929; 35 mm; Adult ♂
No. 9,525; Net 31; 500 F.; April 24, 1929; 35 mm; Adult ♂
No. 9,598; Net 39; 600 F.; April 25, 1929; 38 mm; Adult ♂
No. 9,609; Net 40; 700 F.; April 25, 1929; 39 mm; Adult ♂
No. 9,716; Net 53; 800 F.; April 30, 1929; 33 mm; Adult ♂
No. 9,756; Net 65; 700 F.; May 4, 1929; 38 mm; Adult ♂
No. 9,767; Net 66; 800 F.; May 4, 1929; 32 mm; Adult ♂
No. 9,827; Net 79; 700 F.; May 8, 1929; 34 mm; Adult ♂
No. 10,023; Net 101; 700 F.; May 14, 1929; 39 mm; Adult ♂
No. 9,993; Net 104; 700 F.; May 15, 1929; 44 mm; Adult ♂
No. 24,060; Net 144; 900 F.; May 31, 1929; 38 mm; Adult ♂
No. 10,323; Net 148; 700 F.; June 1, 1929; 42 mm; Adult ♂
No. 10,352; Net 153; 700 F.; June 8, 1929; 38 mm; Trans. Adol. ♂
No. 10,476; Net 170; 500 F.; June 15, 1929; 48 mm; Trans. Adol. ♀
No. 10,508; Net 176; 500 F.; June 17, 1929; 36 mm; Adult ♂
No. 10,520; Net 177; 600 F.; June 17, 1929; 30 mm; Trans. Adol. ♂
No. 10,603; Net 188; 600 F.; June 19, 1929; 34 mm; Adult ♂
No. 10,610; Net 189; 700 F.; June 19, 1929; 33 mm; Adult ♂
No. 10,838; Net 207; 700 F.; June 22, 1929; 75, 125 mm; Trans. Adol. ♀
No. 10,966; Net 222; 1000 F.; June 25, 1929; 60 mm; Trans. Adol. ♀
No. 11,076; Net 233; 600 F.; June 28, 1929; 90 mm; Trans. Adol. ♀
No. 11,087; Net 235; 800 F.; June 28, 1929; 28 mm; Trans. Adol. ♂
No. 11,088; Net 236; 900 F.; June 28, 1929; 40 mm; Adult ♂
No. 11,535; Net 293; 700 F.; July 12, 1929; 33 mm; Adult ♂
No. 11,542; Net 294; 800 F.; July 12, 1929; 37 mm; Adult ♂
No. 11,577; Net 299; 700 F.; July 13, 1929; 38 mm; Adult ♂
No. 11,634; Net 305; 600 F.; July 16, 1929; 37 mm; Adult ♂
No. 11,725; Net 313; 800 F.; July 22, 1929; 35 mm; Adult ♂
No. 11,755; Net 317; 700 F.; July 23, 1929; 35 mm; Adult ♂
No. 11,811; Net 324; 800 F.; July 24, 1929; 31 mm; Trans. Adol. ♂
No. 12,135; Net 356; 700 F.; Aug. 9, 1929; 49 mm; Post-larva ♀
No. 24,147; Net 369; 800 F.; Aug. 14, 1929; 45 mm; Post-larva ♀

[1] Regan 1914, p. 14; Waite, 1916, p. 55; Archey 1922, p. 295.

No. 12,342; Net 374; 600 F.; Aug. 15, 1929; 33, 37 mm; Adult ♂
No. 12,405; Net 382; 900 F.; Aug. 16, 1929; 16 mm; Larva
No. 12,586; Net 394; 900 F.; Aug. 19, 1929; 33 mm; Adult ♂
No. 12,963; Net 411; 700 F.; Sept. 3, 1929; 49 mm; Adolescent ♀
No. 13,063; Net 418; 700 F.; Sept. 4, 1929; 46 mm; Post-larva ♀
No. 13,397; Net 453; 600 F.; Sept. 10, 1929; 161 mm; Trans. Adol. ♀
No. 13,419; Net 460; 700 F.; Sept. 11, 1929; 33 mm; Adult ♂
No. 13,461; Net 465; 800 F.; Sept. 12, 1929; 36 mm; Adult ♂
No. 13,575; Net 479; 600 F.; Sept. 20, 1929; 88 mm; Trans. Adol. ♀
No. 13,630; Net 486; 700 F.; Sept. 21, 1929; 50, 270 mm; Trans. Post-larva, Adult ♀
No. 13,718; Net 495; 800 F.; Sept. 23, 1929; 44, 60 mm; Post-larva, Trans. Adol. ♀
No. 13,848; Net 515; 800 F.; Sept. 27, 1929; 36 mm; Adult ♂
No. 14,712; Net 540; 700 F.; May 6, 1930; 40 mm; Adolescent ♂
No. 14,988; Net 576; 700 F.; May 14, 1930; 35 mm; Adolescent ♂
No. 15,093; Net 589; 700 F.; May 17, 1930; 35 mm; Adult ♂
No. 15,654; Net 646; 600 F.; May 29, 1930; 48 mm; Post-larva ♂
No. 15,871; Net 680; 700 F.; June 7, 1930; 41 mm; Adult ♂
No. 15,967; Net 699; 700 F.; June 13, 1930; 37, 40 mm; Adult ♂
No. 16,526; Net 759; 700 F.; July 2, 1930; 38, 40 mm; Adult ♂
No. 16,645; Net 770; 700 F.; July 4, 1930; 38 mm; Adult ♂
No. 16,721; Net 778; 700 F.; July 5, 1930; 33 mm; Adult ♂
No. 16,776; Net 785; 600 F.; July 7, 1930; 42 mm; Adult ♂
No. 16,842; Net 792; 600 F.; July 8, 1930; 48, 75 mm; Trans. Post-larva, Trans. Adol. ♀
No. 17,033; Net 797; 500 F.; July 15, 1930; 45, 47 mm; Post-larva ♂, Adolescent ♀
No. 17,056; Net 799; 700 F.; July 15, 1930; 37 mm; Adult ♂
No. 17,157; Net 806; 700 F.; July 16, 1930; 34 mm; Adult ♂
No. 17,202; Net 807; 800 F.; July 16, 1930; 36 mm; Adult ♂
No. 17,536; Net 825; 800 F.; Sept. 1, 1930; 38 mm; Post-larva ♂
No. 17,600; Net 829; 600 F.; Sept. 2, 1930; 36 mm; Adult ♂
No. 17,784; Net 838; 600 F.; Sept. 3, 1930; 40 mm; Adolescent ♂
No. 17,790; Net 839; 700 F.; Sept. 3, 1930; 37 mm; Adolescent ♂
No. 18,009; Net 854; 600 F.; Sept. 6, 1930; 35 mm; Trans. Adol. ♂
No. 18,037; Net 858; 1000 F.; Sept. 6, 1930; 35 mm; Trans. Adol. ♂
No. 18,063; Net 859; 500 F.; Sept. 8, 1930; 43 mm; Adolescent ♀
No. 18,091; Net 861; 700 F.; Sept. 8, 1930; 40 mm; Trans. Adol. ♂
No. 18,295; Net 866; 700 F.; Sept. 10, 1930; 33 mm; Trans. Adol. ♂
No. 18,395; Net 875; 600 F.; Sept. 11, 1930; 37 mm; Adolescent ♂
No. 18,444; Net 880; 500 F.; Sept. 12, 1930; 40 mm; Post-larva ♀
No. 18,629; Net 892; 800 F.; Sept. 15, 1930; 117 mm; Trans. Adol. ♀
No. 18,836; Net 917; 600 F.; Sept. 19, 1930; 28 mm; Larva
No. 18,848; Net 919; 700 F.; Sept. 19, 1930; 36 mm; Post-larva ♂
No. 19,153; Net 921; 500 F.; Sept. 20, 1930; 190 mm; Adult ♀
No. 20,532; Net 984; 600 F.; June 2, 1931; 33 mm; Adult ♂

No. 20,658; Net 999; 700 F.; June 5, 1931; 40 mm; Adult ♂
No. 20,821; Net 1016; 500 F.; June 15, 1931; 47 mm; Adolescent ♀
No. 20,872; Net 1022; 700 F.; June 16, 1931; 36, 39 mm; Adult ♂
No. 21,472; Net 1095; 600 F.; July 29, 1931; 44 mm; Trans. Post-larva ♀
No. 21,802; Net 1122; 600 F.; Aug. 3, 1931; 40 mm; Post-larva ♂
No. 21,937; Net 1137; 600 F.; Aug. 6, 1931; 40, 267 mm; Post-larva ♂, Adult ♀
No. 22,161; Net 1156; 500 F.; Aug. 10, 1931; 63 mm; Trans. Adol. ♀
No. 22,221; Net 1165; 900 F.; Aug. 11, 1931; 38 mm; Adult ♂
No. 22,255; Net 1169; 700 F.; Aug. 12, 1931; 40 mm; Adult ♂
No. 22,877; Net 1175; 600 F.; Aug. 14, 1931; 40 mm; Post-larva ♂
No. 22,476; Net 1184; 800 F.; Aug. 15, 1931; 242 mm; Adult ♀
No. 22,618; Net 1200; 600 F.; Aug. 19, 1931; 36 mm; Adult ♂
No. 22,673; Net 1210; 1000 F.; Aug. 20, 1931; 39 mm; Adult ♂
No. 22,783; Net 1225; 1000 F.; Aug. 26, 1931; 100 mm; Trans. Adol. ♀
No. 22,841; Net 1235; 500 F.; Aug. 29, 1931; 34 mm; Adult ♂
No. 22,949; Net 1242; 600 F.; Aug. 31, 1931; 28 mm; Trans. Adol. ♂
No. 23,002; Net 1249; 700 F.; Sept. 1, 1931; 32 mm; Adult ♂
No. 23,054; Net 1255; 600 F.; Sept. 1, 1931; 37 mm; Adult ♂
No. 23,097; Net 1260; 500 F.; Sept. 4, 1931; 120 mm; Trans. Adol. ♀
No. 23,100; Net 1261; 600 F.; Sept. 4, 1931; 35 mm; Adult ♂
No. 23,148; Net 1270; 500 F.; Sept. 7, 1931; 45 mm; Adolescent ♀
No. 23,163; Net 1271; 600 F.; Sept. 7, 1931; 32 mm; Adult ♂
No. 23,286; Net 1286; 900 F.; Sept. 10, 1931; 45, 51 mm; Post-larva ♂, Trans. Adol. ♀
No. 23,331; Net 1294; 900 F.; Sept. 12, 1931; 36 mm; Adult ♂
No. 23,350; Net 1296; 600 F.; Sept. 14, 1931; 36, 40 mm; Post-larvae ♂
No. 23,366; Net 1297; 700 F.; Sept. 14, 1931; 35 mm; Adolescent ♂
No. 23,545; Net 1308; 100 F.; Sept. 16, 1931; 16, 17, 20 mm; Larvae
No. 23,512; Net 1309; 100 F.; Sept. 16, 1931; (8), 18 to 25 mm; Larvae
No. 23,664; Net 1326; 600 F.; Sept. 19, 1931; 35 mm; Adolescent ♂
No. 23,900; Net 1332; 600 F.; Oct. 28, 1931; 30 mm; Trans. Adol. ♂
No. 23,941; Net 1337; 600 F.; Oct. 29, 1931; 45 mm; Postlarva ♀

The following specimens have been cleared and stained in order to study the skeleton: Nos. 8,733 (KOH No. 2019); 10,352 (KOH No. 2015); 10,476 (KOH No. 2021); 11,076 (KOH No. 328a); 11,087 (KOH No. 329); 11,088 (KOH No. 328b); 13,630a (KOH No. 2023); 15,967a, b (KOH No. 2028a, b); 16,776 (KOH No. 2029); 18,395 (KOH No. 2025); 18,444 (KOH No. 2024); 20,658 (KOH No. 1185); 20,821 (KOH No. 2020); 21,472 (KOH No. 2022); 21,937 (KOH No. 2013); 23,331 (KOH No. 1184); No. 23,350a (KOH No. 1025); 23,545b (KOH No. 1015b); 23,545c (KOH No. 1015c); 23,512h (KOH No. 2026).

The following material has been filed: Colored plates B277 and

B651; outline drawings B957–B986 incl; photographs B5361-L, B5389-L, B5585, B5587, B6215-L, B6275.

A specimen of *Idiacanthus panamensis* measuring 360 mm in standard length was used in connection with the study of the osteology of *I. fasciola* for purposes of comparison. This exceptionally large female (No. 5982, KOH No. 29) was taken by the Arcturus Oceanographic Expedition of the New York Zoological Society in the Gulf of Panama in May, 1925 at a depth of 750 fathoms.

Synonymy and References

Idiacanthus fasciola:

Peters 1876, p. 847. (2 specimens; 50, 130 mm; surface; north of Australia and north of New Guinea; *type specimens*).

Goode and Bean 1895, p. 128. (Mention of types).

Brauer 1906, p. 60; figs. 17–20; pl. iv, figs. 2–3. (2 specimens; 180, 147.5 mm; 594–2500 m.; off Sumatra and between Chagos and Seychelles Islands; also 1 young specimen, 2000 m, west of Chagos.

Brauer 1908, pp. 64, 176, pl. XXVI, figs. 14–27; pl. XXVII, figs. 1–14. (Structure of light organs and eyes).

Weber 1913, p. 15. (2 specimens; 45, 180 mm; 1536, 1600 m; Manipa Strait and Halmahera Sea).

Weber and Beaufort 1913, p. 108, fig. 37. (Records of occurrence in Indo-Australian region and description of Weber's "Siboga" specimen).

Parr 1927, p. 116; fig. 62. (4 specimens; 80 to 225 mm; 6000–10,000 ft. wire; Bermuda and Bahamas).

Beebe 1929, p. 13 (1 specimen; 122 mm; 600 fath.; Hudson Gorge).

Regan and Trewavas 1930; p. 129; figs. 20B, 22, 23, 125, 126. (250 advanced female specimens: 46 to 276 mm; 0–3000 m. wire; Atlantic. 30 so-called post-larvae (young females and young and adult males); 33 to 44 mm; 300–500 m. wire; Atlantic. 1 previously unrecorded British Museum specimen; 104 mm; Indian Ocean.

Roule and Angel 1933, p. 24. (10 specimens; 115 to 320 mm; 0–250–4000 M; eastern Atlantic.

Beebe 1933c, p. 39. (Preliminary account of the present Bermuda material).

Bathyophis ferox:

Günther 1878, p. 181. (1 specimen; 195 mm; 2750 fath.; middle of North Atlantic; preliminary type description).

Idiacanthus ferox:

Günther 1887, p. 216, pl. LII, fig. D. (Supplementary description of type).

Goode and Bean 1895, p. 129, fig. 151. (Mention of type).

Jordan and Evermann 1896, p. 605. (Mention of type).

Murray and Hjort 1912; pp. 86, 87, 612, 618; fig. 67b. (10 or more specimens; at least up to 220 mm; surface to 1500 fath.; between Azores, Canaries, and northwest Africa).

Stylophthalmus paradoxus (partim):

Brauer 1902, p. 298. (Preliminary type description).

Brauer 1906; p. 67, pl. V, figs. 1–7. (Detailed description. Entire series, only some of which were *Idiacanthus*, contained 35 specimens; 10.5 to 40 mm; 1500 to 4000 m.; west coast of South Africa, Antarctic off Bouvet Island, Indian Ocean).

Brauer 1908, p. 178. (Dissection of eye).

Beebe 1929, p. 9. (2 specimens; 4.3 and 41 mm; 600 fath.; Hudson Gorge. *Partim*).

Beebe, 1933a, p. 180. (Records of shallow water occurrences of Bermuda specimens. *Partim*).

?Idiacanthus aurora:

Waite 1916, p. 53, pl. V, fig. 1. (1 specimen; 408 mm; 1450 fath.; off Macquairie Island, Australia).

Regan 1916a, p. 378. (Suggestion as to the synonymy of *I. aurora* with *I. niger*).

Archey 1922, p. 296. (Comparative measurements of *I. aurora* and *I. niger*).

Regan and Trewavas 1930, p. 129. (Tentative synonymy of *I. aurora* with *I. fasciola*).

Bibliography of References Consulted in the Present Paper

Archey, G.

1922 A Second Specimen of *Idiacanthus niger* Regan from New Zealand. New Zealand Journ. Sci. Tech. Wellington 5.

Beebe, W.

1929 Deep Sea Fish of the Hudson Gorge. Zoologica, Vol. XII, No. 1.

1930 A Quarter Mile Down in the Open Sea. Bull. N. Y. Zool. Soc., Vol. XXXIII, No. 6.

1931 Bermuda Oceanographic Expeditions 1929–1930. Introduction. Zoologica, Vol. XIII, No. 1.

1931 Bermuda Oceanographic Expeditions 1929–1930. List of Nets and Data. Zoologica, Vol. XIII, No. 2.

1932 Bermuda Oceanographic Expeditions 1931. Individual Nets and Data. Zoologica, Vol. XIII, No. 3.

1933a Preliminary Account of Deep-Sea Dives in the Bathysphere with Especial Reference to One of 2200 Feet. Proc. Nat'l. Acad. Sci. Vol. 19, No. 1.

1933b Deep-sea Fishes of the Bermuda Oceanographic Expeditions. Introduction. Zoologica, Vol. XVI, No. 1.

1933c New Data on the Deep-sea Fish *Stylophthalmus* and *Idiacanthus*. Science, Vol. 78, No. 2026.

Brauer, A.

1902 Ueber den Bau der Augen einiger Tiefseefische. Verh. D. Zool. Ges. 1902. Leipzig.

1906 Die Tiefsee Fische, I. Systematischer Teil. Wiss. Ergebnisse Deutsch. Tiefsee. Exp. Valdivia, Vol. 15, Lief 1.

1908 Die Tiefsee Fische, II. Anatomischer Teil. Wiss. Ergebnisse Deutsch. Tiefsee. Exp. Valdivia, Vol. 15, Lief 1.

Garman, S.

1899 The Fishes. Report on an exploration . . . by the U. S. Fish Commission Steamer "Albatross," during 1891. Mem. Mus. Comp. Zool. Harvard Coll., Cambridge, Mass.

Gilbert, C. H.

1891 Preliminary Report on the Fishes Collected by the Steamer "Albatross" on the Pacific Coast of North America during the year 1889. Proc. U. S. Nat. Mus., Vol. 13, 1890 (1891).

Goode, G. B., and Bean, T. H.

1895 Oceanic Ichthyology. A Treatise on the Deep-sea and Pelagic Fishes of the World. Special Bull. U. S. Nat. Mus.

Günther, A.

1878 Preliminary Notes of Deep-Sea Fishes Collected During the Voyage of H. M. S. "Challenger." Ann. Mag. Nat. Hist. (5) 2.

1887 Report on the Deep-sea Fishes. Rept. Sci. Res. "Challenger," Vol. 22.

Holt, E. W. L., and Byrne, L. W.

1907 Biscayan Plankton Collected During a Cruise of H. M. S. "Research" 1900. Pt. 10: the Fishes. Trans. Linn. Soc. London, Vol. 10, pt. 7.

JORDAN, D. S.
1923 A Classification of Fishes. Including Families and Genera as Far as Known. Stanford Univ. Pub. Biol. Sci. Palo Alto, Cal. 3.
JORDAN, D. S., AND EVERMANN, B. W.
1896 The Fishes of North and Middle America, Vol. 1. Bull. U. S. Nat. Mus.
LO BIANCO, S.
1903 Le Pesche Abissali Eseguite da F. A. Krupp col Yacht "Puritan" nelle Adiacenze di Capri ed in Altre Localita del Mediterraneo. Mitth. Zool. Stat. Neapel., 16.
MAZZARELLI, G. F.
1912 Studi Sui Pesci Batipelagici dello Stretto di Messina. Revist. Mens Pesca, Pavia, 7.
MURRAY, SIR J., AND HJORT, J.
1912 The Depths of the Ocean. A General Account of the Modern Science of Oceanography Based Largely on the Scientific Researches of the Norwegian Steamer "Michael Sars" in the North Atlantic.
NORMAN, J. R.
1930 Oceanic Fishes and Flatfishes Collected in 1925–1927. Discovery Reports, Vol. 2.
PARR, A. E.
1927 Scientific Results of the Third Oceanographic Expedition of the "Pawnee," 1927. The Stomiatoid fishes of the suborder Gymnophotodermi. Bull. Bingham Ocean. Coll. N. York, 3, Art. 2.
PETERS, W. C. H.
1876 Uebersicht der Während der von 1874 bis 1876—Übersandten Fische. Monatsb. Akad. Wiss. Berlin.
REGAN, C. T.
1914 Diagnosis of New Marine Fishes Collected by the British Antarctic "Terra Nova" Expedition. 2. Fishes from New Zealand. Ann. Mag. N. H. (8) 13.
1916a Bibliographical Notice. Antarctic and Subantarctic Fishes. Ann. Mag. N. H. (8) 18.
1916b Larval and Post-larval Fishes. British Antarctic ("Terra Nova") Exped. Zool. 1, No. 4.
REGAN, C. T., AND TREWAVAS, E.
1930 The Fishes of the Families Stomiatidae and Malacosteidae. Danish "Dana" Exped. 1920–1922. Ocean. Rep. 6, 1930.
ROULE, L., AND ANGEL, F.
1930 Larves et Alevins de Poissons Provenant des Croisieres du Prince Albert de Monaco. Res. Camp. Sci. Monaco, Fasc. 79.
1933 Poissons Provenant des Campagnes du Prince Albert I de Monaco. Res. Camp. Sci. Monaco, Fasc. 86.
SANZO, L.
1915 Notizie Ittiologiche. Monit. Zool. Ital., 1915, 26.
1920 *Stylophthalmoides Lobianco* Mazzarelli e *St. mediterraneus* Mazzarelli . . . Roma Mem. Acc. Lincei Ser. V, 10.

TAANING, A. V.
1931 Postlarval Stages of *Bathylagus* from the North Atlantic. Vidensk. Medd. Dansk. Naturh. Foren. 92.
THOMPSON, W. F.
1916 Fishes Collected by the U. S. Bureau of Fisheries Steamer "Albatross" During 1888. Proc. U. S. Nat. Mus. Vol. 50, 1916.
WAITE, E. R.
1916 Fishes, Australasian Antarctic Expedition. Sci. Rep. Ser. C. 3 Pt. 1.
WEBER, M.
1913 Die Fische der Siboga-Expedition. Siboga-Expeditie, Monog. 57, Livr. 65.
WEBER, M. AND BEAUFORT, L. F. DE
1913 The Fishes of the Indo-Australian Archipelago. II. Leiden.